

Proceedings



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VOLUME 31 NUMBER 12

Phase-Control Circuit

Transconductance Limitation

Stability of I-F Amplifiers

Reciprocity in Antenna Theory

Antenna Arrays Around
Cylinders

Center-Driven Antenna

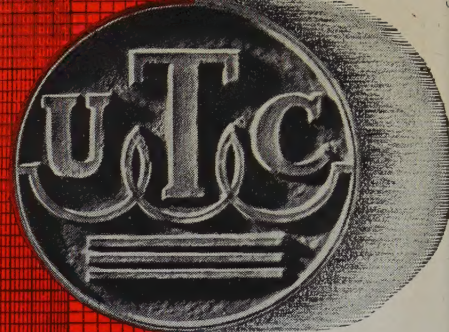


General Electric Photo

SUPER-ARCTIC COLD GREETS RADIO ENGINEERS ON TEST JOB

Institute of Radio Engineers

DESIGNS for WAR



FILTERS

INDUCTOR LOSS = 0.5 AH

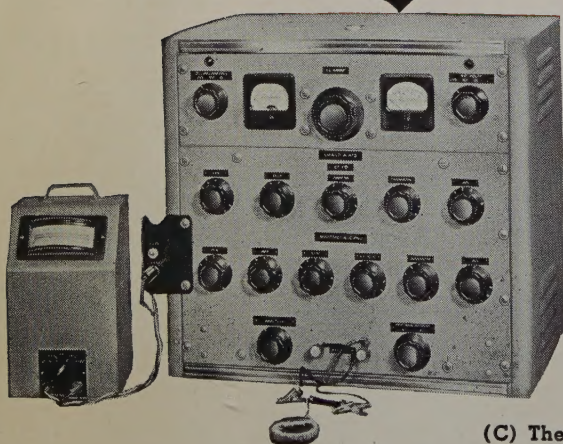
$R = 5000 \Omega$

LEVEL = 10 V



(A) Filter performance is dependent upon three major factors, basic design... Q of coil and capacitor elements... and precision of adjustment. The superiority of UTC products in this field has been effected through many years of research and development on core materials and measuring apparatus. We illustrate below a typical filter formula and some of the UTC apparatus used to determine quantitative and qualitative values:

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(B) The UTC inductance bridge is capable of four digit accuracy and covers a range from extremely low values to over 100 Hys. The effective resistance and inductance values are direct reading, eliminating the possibility of error in conversion.



(C) The UTC oscillator is direct reading, where the frequency desired is set as in a four digit decade box, and is accurate within 1 cycle at 1,000 cycles. The range is 10 cycles to 100 kc. Accuracy of this type is essential with filters having sharp attenuation characteristics. This instrument is augmented by a UTC harmonic analyzer for the output measuring device.



(D) The UTC Q meter is a unique device which has helped considerably in the development of the special core materials used in our filters. It is also of importance in maintaining uniform quality in our production coils. The Q is read directly and covers the entire range of possible Q factors over the entire audio frequency band.

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Radio-and-Electronic Engineering Contributions to Victory.....	S. W. Muldowny	651
G. W. Pierce.....		652
Vacuum-Tube Phase-Control Circuit.....	S. C. Coroniti	653
Correction to "Network Theory, Filters, and Equalizers—Part II," by Frederick Emmons Terman.....		656
Correction to "Heat-Conduction Problems in Presses Used for Gluing of Wood," by George H. Brown.....		656
Correction to "Correspondence on 'A Useful Network Theorem', by J. Millman," by Norman E. Polster.....		656
Theoretical Limitation to Transconductance in Certain Types of Vacuum Tubes.....	J. R. Pierce	657
Neutralization of Screen-Grid Tubes to Improve the Stability of Intermediate-Frequency Amplifiers.....	C. A. Hultberg	663
The Principle of Reciprocity in Antenna Theory.....	M. S. Neiman	666
Antenna Arrays Around Cylinders.....	P. S. Carter	671
The Radiation Field of a Symmetrical Center-Driven Antenna of Finite Cross Section.....	Charles W. Harrison, Jr., and Ronold King	693
Corrections to "The Distribution of Current Along a Symmetrical Center-Driven Antenna," by Ronold King and Charles W. Harrison, Jr.....		697
Section Meetings.....		698
Institute News and Radio Notes		
Board of Directors.....		699
Executive Committee.....		699
Contributors.....		700
I.R.E. People.....		34A
Section Meetings.....		40A
Membership.....		42A
Incorrect Addresses.....		48A
Positions Open.....		50A
Television Relay Network.....		58A
Advertisers' Index.....		64A

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Commercial and engineering activities are so closely interwoven and so dependent on each other in the radio-and-electronic field that the viewpoints of the business leaders of the industry are of major interest and importance to the engineers. The President of the National Union Radio Corporation, upon invitation, has prepared the following "guest editorial" which, presented in the form in which it was received, will doubtless encourage and stimulate the readers of the PROCEEDINGS to even greater efforts toward that victory which the Allied Nations will undoubtedly achieve.

The Editor

Radio-and-Electronic Engineering Contributions to Victory

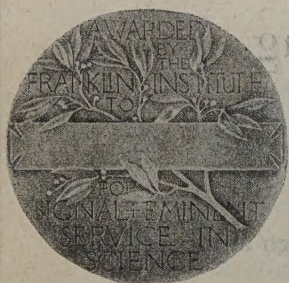
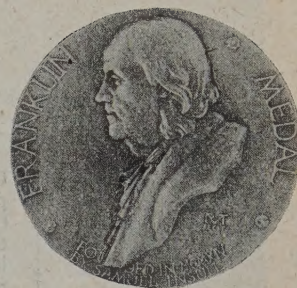
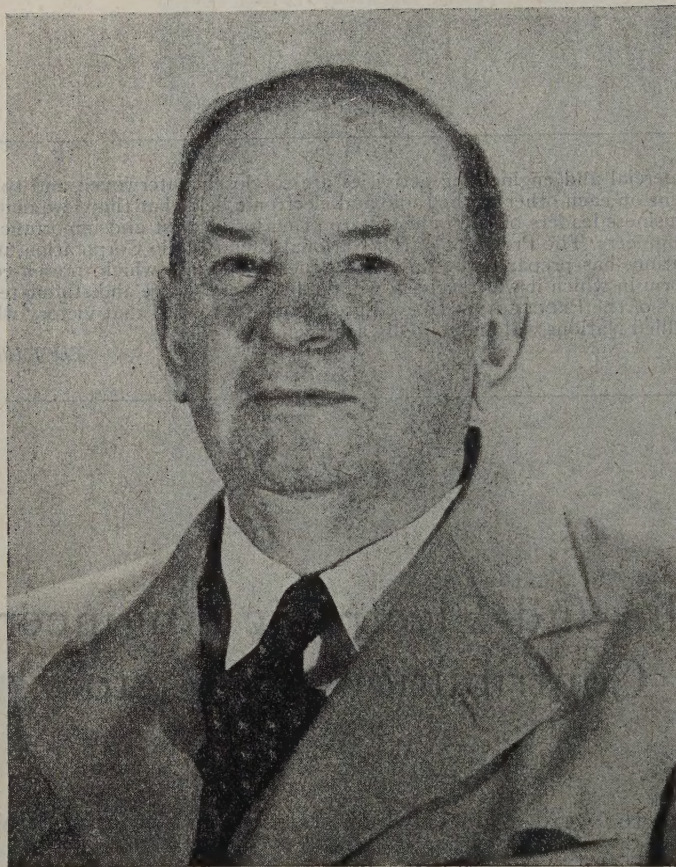
S. W. Muldowny

I like the definition of the word engineer which states: "one who carried through an undertaking by skill or astuteness."

Today's undertaking is Victory and the skill and astuteness of American radio engineers is written in the continued advance of our armed forces on land, sea, and in the air. The genius which has made radio such a mighty weapon of offense and defense was certainly latent in our radio engineers before Pearl Harbor, but the inspiration of an aroused nation at war has brought these men to untold heights in their contributions to our war machine. Radio engineering has come of age. Unencumbered by economic pressures which tend to limit the rapidity of technical advances in a normal commercial market, our radio engineers have turned on brain power and won the admiration of our allies and the respect of our enemies. To say that the future of the radio engineer is bright is a conservative statement. If the profession has grown in stature as it has under the duress of emergency conditions, certainly it is the "white hope" toward which we look.

The radio industry recognizes the debt it owes to the skill and astuteness of its engineers. The radio industry looks forward to, and expects the application of this same brain power to peacetime activities. We believe in our engineers. We know that having climbed to unbelievable pinnacles in the Victory undertaking they will rise to even greater heights in dreaming through to practical solutions of commercial needs in a rebuilding of our war-torn world. I can view a thousand times the wonders which I see worked in our laboratories today and still have a feeling of awe at the ingenuity of our engineers from whose brains these miracles have come.

The magic of the word electronic has swept the nation, and some have felt the art may have been oversold. Truthfully, however, we stand but on the threshold of changes in living, in travel, in manufacturing methods, so vast that the prospect is breath taking. It is the electron tube and electronic principles which form the master key to unlock many doorways to a new kind of civilization. The radio-electronic engineer holds this key and thus holds today's power to destroy our enemies, tomorrow's power to bring us the fullest life ever known to mankind.



G. W. Pierce

An eminent member of the Institute is the recipient of an additional honor. Professor Pierce received the Franklin Medal of the Franklin Institute, on April 21, 1943. He was a vice president of The Institute of Radio Engineers in 1915, a member of its Board of Directors from 1915 to 1921, and its president in 1918 and 1919. He was awarded its Medal of Honor in 1929.

The latest recognition of his scientific accomplishments "... is awarded annually ... to those workers in physical science or technology ... whose efforts ... have done most to advance a knowledge of physical science or its applications." The medal citation, as read by Dr. Henry Butler Allen, Director of the Franklin Institute at the presentation, stated that the award was "in recognition of his outstanding inventions, his theoretical and experimental contributions in the field of electric communication, and his inspiring influence as a great teacher."

In the presentation speech, Dr. Allen mentioned numerous high lights in Professor Pierce's career. Among these were the following. Professor Pierce has "held the chairs of Rumford professor of physics and Gordon McKay professor of communication engineering at Harvard University." He is "the author of thirty or forty valuable papers in physics and electrical communication, and is the author of two standard books, 'Principles of Wireless Telegraphy' (1910) and 'Electric Oscillations and Electric Waves' (1920)." In studying in the early days of radio communication the action of crystal detectors, he "began a series of systematic investigations to find what other materials possessed the same rectifying properties, and also to discover to what this property is due." He showed that certain then-current theories were inadequate.

He later developed an advanced form of mercury-vapor detector and amplifier, and devised methods for its use "equivalent to the

present use of the mercury tube employed to record variable-density sound-on-film." During World War I, he investigated devices for locating submerged submarines, and produced an ingenious and novel form of electrical compensator for use with them.

Turning his attention to piezoelectric oscillators, Professor Pierce "began the study of suitable oscillator circuits for use with quartz crystals. He produced three fundamental types of circuit employing one tube and one set of electrodes on the crystal" which constituted a "considerable simplification" of prior practice. He also "recognized that the phenomenon of magnetostriction could be used to control the frequency of oscillators by mechanical resonance ..." and "devised a number of oscillator circuits for making use of this property."

In an extemporaneous and graceful speech of acceptance of the medal, Professor Pierce described a novel and interesting series of experiments on an analysis of the "songs" of insects. A parabolic horn reflector was provided with a piezoelectric sound detector at its focus. The supersonic energy radiated by the "singing" insect (e.g., a cricket) was then electrically analyzed as to frequency, and, after heterodyning, converted into audible sound from a loudspeaker and also recorded photographically. The details of the experiments and their results present an unusual combination of electrical skill and entomological aptitude.

In concluding his remarks, Dr. Allen said in part: "Professor Pierce's influence has been impressed widely upon the field of electric communication, for the majority of the men who are engaged upon important work in radio engineering all over the world have studied in his classes. ... Pierce recognized that the art of communication was neither physics nor engineering, but a combination of the two."

Analysis and Characteristics of Vacuum-Tube Thyatron Phase-Control Circuit*

SAMUEL C. CORONITI†, ASSOCIATE, I.R.E.

Summary—An explanation is presented of a vacuum-tube phase-control circuit of the RC type. It is shown that the effective phase angle between the plate- and grid-to-cathode voltages is influenced by the direct rectified current flowing through the control vacuum tube. The effect of the thyatron grid resistance on the stability of operation is discussed. Curves are given to illustrate the degree of control by various types of tubes.

BY SUBSTITUTING a vacuum tube for the resistance in the RC component of a phase-control circuit such as Fig. 1, a small grid voltage can be made to control effectively large electrical power. This paper gives an analysis and some operational characteristics of this type of circuit.

In the circuit of Fig. 1, the magnitude of the load current I_L is a function of the phase angle between the plate-cathode and grid-cathode voltage of the thyatron tube.¹⁻⁴ Before ionization of the gas within the tube, their magnitudes and phase angles are determined from the alternating-current steady-state conditions of the circuit. In the vacuum-tube-thyatron phase-control circuit, the magnitude of the thyatron grid voltage and its effective phase angle with respect to the plate voltage is determined not only by the alternating-current steady-state conditions, but also by the transient response of the circuit.

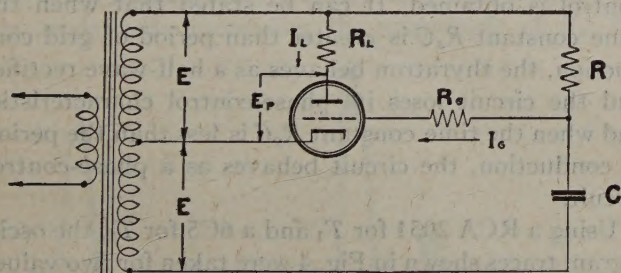


Fig. 1—Basic phase-control circuit.

Fig. 2 is a schematic diagram in which the vacuum tube T_2 replaces the resistance R of Fig. 1. The plate-to-cathode current I_3 at any instant defines its value of resistance, the value of which can be varied from several hundred ohms to several megohms. The operation of this circuit differs in two respects from the circuit

of Fig. 1. First, the vacuum-tube resistance is variable for the cycle of operation, and second, current flows through the vacuum tube only during the period of the cycle when the plate is at a positive voltage with respect to its cathode; that is, T_2 behaves as a half-wave rectifier.

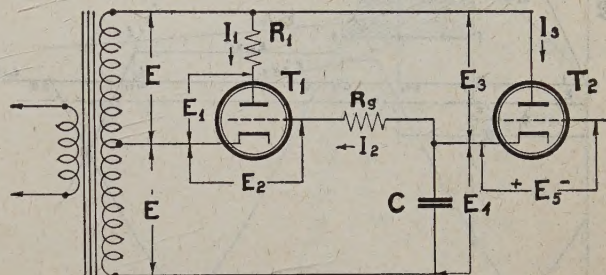


Fig. 2—Vacuum-tube phase-control circuit.

The internal resistance of the T_2 at any time is a function of its grid-bias voltage E_5 and the instantaneous value of the plate-to-cathode voltage E_3 . The instantaneous plate voltage E_3 is equal to the secondary voltage $2E$ minus the instantaneous voltage E_4 , which is equal to the algebraic sum of the direct and alternating voltages across the capacitor C . The rectification action of tube T_2 raises the direct-current potential of capacitor C to some positive value, the magnitude of which is determined by the internal resistance of the tube, and by the nonconducting period of the thyatron. Since T_2 has a finite resistance during the period that its plate voltage is positive with respect to the cathode, an alternating voltage exists across C . For all practical considerations it can be considered to be constant and to be equal to the static resistance because in the application of the circuit the grid bias E_5 is much greater than recommended values given by e_p-i_p characteristics of the vacuum tubes. For instance, when a 6C5 is used, the value of E_5 is -25 volts, and E_3 is equal to 250 volts.

During the nonconducting period of the thyatron tube T_1 its grid-to-cathode voltage will also be the algebraic sum of the direct and alternating voltages.

Fig. 3 is a graphical representation of the plate and grid voltage of the thyatron tube T_1 . For the sake of simplicity, it is assumed that there is no time lag between the application of the switch and the magnitude of the voltage E ; that is, when the voltage is applied to the circuit, it has an initial value of zero and progresses toward positive values. In the interval oa , the plate and grid voltage of T_1 varies as shown by curves E_1 and E_2 a.s., whereas the direct voltage on the grid due to the rectification action of T_2 rises exponentially as shown by curve E_2 d.s.. When the algebraic sum of these

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† 145 Lake View Avenue, Cambridge, Massachusetts.

¹ W. J. Nottingham, "Characteristics of small grid-controlled hot cathode mercury arcs or thyratrons," *Jour. Frank Inst.*, vol. 211, pp. 271-301; March, 1931.

² A. W. Hull, "Hot cathode thyratrons," *Gen. Elec. Rev.*, vol. 37, pp. 390-399; July, 1929.

³ H. J. Reich, "Theory and Applications of Electron Tubes," McGraw-Hill Book Co., New York, N. Y., 1939, pp. 449-452.

⁴ M. M. Morack, "Voltage impulses for thyatron grid control," *Gen. Elec. Rev.*, vol. 37, pp. 288-295; June, 1934.

voltages is equal to or greater than the critical grid voltage E_c of the thyatron, the gas within it ionizes, resulting in a flow of current I_1 (Fig. 2). For instance, at $\omega t = \omega t_1$ the total grid voltage is represented by line $ae = ac - ad = E_c$ where a, c, d, e are points as shown on the volt- ωt diagram of Fig. 3.

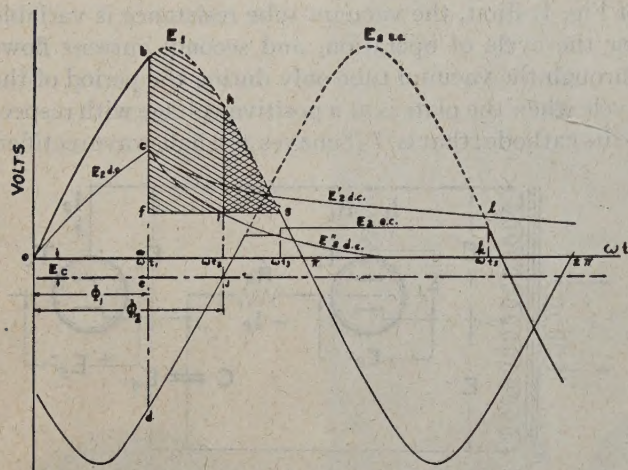


Fig. 3—Graphical operation of circuit of Fig. 2.

The shaded area bfg is proportional to the direct current flowing through the resistance R_1 . The effective phase angle between the plate and the grid is denoted by Φ_1 . The voltage E_1 across the plate will be reduced to the internal voltage drop of the thyatron. Now without rectification, complete ionization within the thyatron tube occurs when the grid-voltage curve $E_{2 \text{ a.c.}}$ intersects the critical-voltage curve E_c at points j or $\omega t = \omega t_2$. In this instant the load current I_1 is proportional to the crosshatched area hig . The phase angle is denoted by Φ_2 . Hence, the presence of rectification has the effect of shifting the zero axis of the alternating grid voltage, $E_{2 \text{ a.c.}}$, by some positive value equal to the ordinate alternating current. Stating it differently, the effective phase angle between the grid and plate voltage is decreased from angle Φ_2 to angle Φ_1 . The effective phase angle is definitely a function of the static resistance of T_2 for a given value of E_5 and E_3 , and of the value of the capacitor C . Increasing or decreasing the negative value of the grid voltage E_5 increases or decreases the phase angle Φ_2 , and decreases or increases the direct voltage on the capacitor C . That is, the effective phase angle Φ_1 can be increased or decreased by increasing or decreasing the negative bias value of E_5 , or by decreasing or increasing the value of the capacitor C .

The plate current I_1 and the grid current I_2 flow through the thyatron for different periods of the cycle. The plate current is sustained as long as the plate-to-cathode voltage E_1 has a value equal to or greater than the ionization potential of the gas. Hence, it flows during the interval $\omega t_3 - \omega t_1$. The grid current flows as long as the effective grid voltage E_2 is greater than the value necessary to sustain the ionization of the gas within the grid-cathode region of the tube. The alternating-current component of the grid voltage acquires the shape shown by the solid line $E_{2 \text{ a.c.}}$. This voltage is not to be

confused with the grid voltage E_2 . The sudden jump of $E_{2 \text{ a.c.}}$ at ωt_3 is attributed to the decrease of conduction between the grid-cathode space caused by the collapse of ionization between the grid and plate region.

So far the effect of the grid resistance R_g on the behavior of T_1 has been neglected.

During the period oa the condenser C in Fig. 3 accumulates a positive charge. At $\omega t = \omega t_1$, the gas within the thyatron ionizes, thereby providing a leakage path for the charge on the capacitor from the grid to the cathode within the thyatron tube. The accumulated charge on the condenser will leak off through the grid resistance, the rate of leakage depending on the value of R_g and C . The charge leaks off during the interval $\omega t_5 - \omega t_1$.

Suppose that the values of R_g and C are such that the charge on the condenser decreases as shown by curve $E'_{2 \text{ d.c.}}$. At ωt_5 the direct-current potential across the condenser is given by the ordinate kl , and it remains at this value throughout the balance of the period of the cycle of E_1 . Since this value is positive, the thyatron will conduct when its plate potential acquires an extremely small positive potential very shortly after $\omega t = 2\pi$. Half-wave rectification results and no phase control is accomplished.

In order to have effective phase control, it is necessary to dissipate completely the charge on C during the interval $\omega t_5 - \omega t_1$. This requirement can be satisfied by reducing the value of R_g or C . It is preferable to decrease R_g . If these values are chosen such that the discharge occurs along the curve $E''_{2 \text{ d.c.}}$, effective phase control is obtained. It can be stated that when the time constant $R_g C$ is greater than period of grid conduction, the thyatron behaves as a half-wave rectifier and the circuit loses its phase-control characteristic, and when the time constant $R_g C$ is less than the period of conduction, the circuit behaves as a phase-control circuit.

Using a RCA 2051 for T_1 and a 6C5 for T_2 , the oscillogram traces shown in Fig. 4 were taken for two values

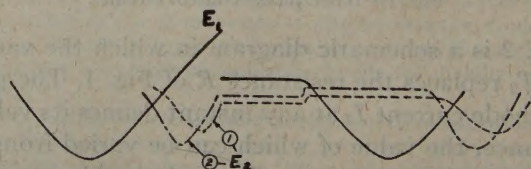


Fig. 4—Trace of oscillograms of the effect of R_g .
 ----- Curve 1, $R_g = 0.1$ megohm
 - - - - - Curve 2, $R_g = 0.01$ megohm

of grid resistances R_g . Traces (1) and (2) were taken with $R_g = 0.1$ and 0.01 megohm, respectively, indicating that the direct positive voltage $E_{2 \text{ d.c.}}$ is greater when $R_g = 0.1$ megohm than when $R_g = 0.01$ megohm.

Note also that there is a difference of phase-angle shift between curves (1) and (2). In the analysis of Fig. 3, it was assumed that the initial charge on the condenser C was zero. That it is not so is evident from Fig. 4. During the conduction period from grid to cathode of T_1 less charge leaks off for the case of $R_g = 0.1$

megohm than for $R_g = 0.01$ megohm. Hence, when the cycle of operation repeats, the direct voltage across C will be greater for $R_g = 0.1$ megohm than for $R_g = 0.01$ megohm.

The behavior of the grid current I_2 is shown in Fig. 5 which is an oscillographic record of the potential across the grid resistance R_g . The high side of the cathode-ray oscilloscope was connected on the condenser side of the grid resistor, and the ground was connected at the grid of the thyatron. The increase in voltage across the resistance R_g from point O to A can be attributed to the flow of very small grid current before total ionization results in the gas. At the instant ionization occurs, the voltage drop across R_g decreases to some negative value, as shown by point C , and then surges back to some positive value, as shown by point D . This can be explained by the fact that at the instant of ionization a large charging current flows from plate to grid to capacitor C charging the capacitor by an amount equal to the difference of direct-current potential across C and the potential of plate T_1 at the instant of ionization. The charging time is approximately equal to $R_g C$ or 1×10^{-5} second. From points D to E , the charge on the capacitor is dissipated, the discharge path being R_g and through the lower half of the secondary winding of the transformer. The time constant for discharge is large because of the large inductance. Point B indicates the collapse of ionization between the plate and the grid. The oscillations shown between points B and F can be caused by the behavior of positive ions within the grid-cathode space⁵ of the T_1 . The frequency of oscillation was approximately 5000 cycles per second. By increasing the magnitude of R_g , the

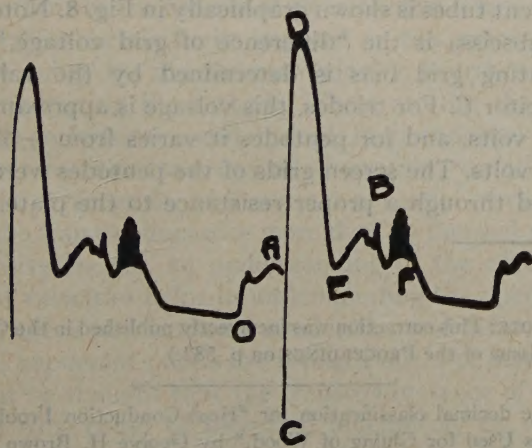


Fig. 5—Oscillogram of grid current I_2 .

$T = 6C5$ $I_1 = 430$ milliamperes
 $C = 0.001$ microfarad $I_2 = 75$ microamperes
 $R_g = 10,000$ megohms $E_g = 18.6$

amplitude and the duration of oscillations were decreased. By increasing the value of capacitor C the amplitude and frequency of oscillation decreased but the duration increased.

Fig. 6 shows experimental curves representing the

relationship of load current I_1 and grid voltage E_g for values of C equal to 0.001, 0.01, 0.1, and 1 microfarad.

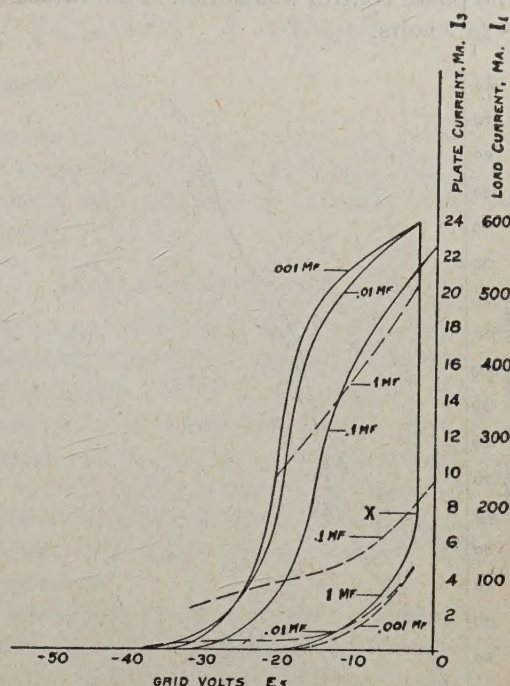


Fig. 6—Effect of capacitance on load current and plate current. 6C5 curves. $R_g = 10,000$ megohms.

Plate-current curves ———

Load-current curves - - - -

Note: The thyatron fired continuously at X .

T_1 and T_2 were a FG57 thyatron and a 6C5. R_1 and R_g were 187 ohms and 10,000 ohms, respectively. For a given value of capacitance C the load current increases with a decrease of negative bias E_g on the grid of T_2 . Its internal resistance is decreased, thereby decreasing the phase angle between the grid and plate of T_1 . As a result, the T_1 will conduct over a long period of time, since the conduction period of the thyatron is inversely proportional to the phase angle.

For a value of C equal to 1 microfarad, the load current I_1 changed abruptly from 165 to 600 milliamperes (maximum current) when E_g was equal to -2.5 volts. This indicates that the capacitor C was raised to a positive direct-current potential which was unable to decrease during the grid-conduction period to a value lower than the ionization potential of the gas within T_1 . The circuit, as a result, behaved as a half-wave rectifier and lost its phase-control characteristic. Upon increasing the value of R_g , the circuit behaves as a half-wave rectifier for larger values of negative grid voltages E_g . For instance, for $R_g = 0.1$ megohm, the value of E_g was -28 volts, and for $R_g = 1$ megohm, the bias required to affect any measure of control is -282 volts which is much greater than value ordinarily used in practice.

As the value R_g is increased, the value of C , at which T_1 behaves as a half-wave rectifier, decreases. Stating it in another way, the value of the negative voltage E_g must be increased in order to have phase control. For instance, for $R_g = 1$ megohm and $C = 0.1$ microfarad, no

⁵ W. G. Shepherd, "Deionization considerations in a harmonic generator employing a gas-tube switch," *Proc. I.R.E.*, vol. 31, pp. 66-74; February, 1943.

phase control was obtained for a value of E_s less than -25.4 volts. For $R_g = 10$ megohms and $C = 0.01$ microfarad, no phase control was obtained for values E_s less than -25.9 volts.

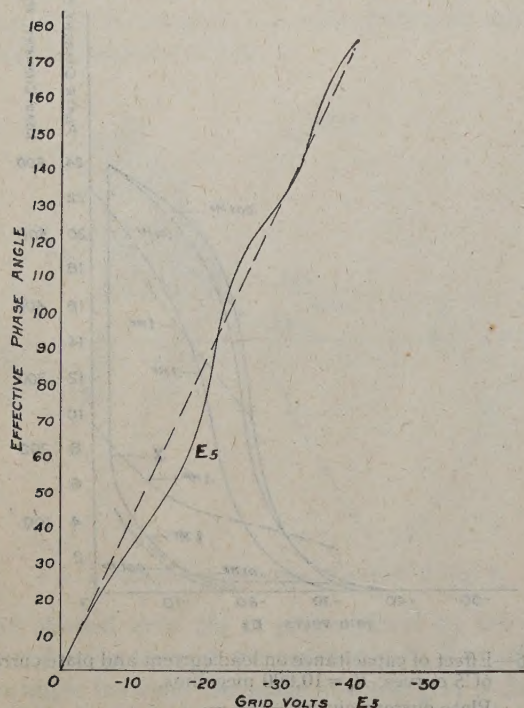


Fig. 7—Phase angle versus E_s .

$$\begin{aligned}\phi &= 2 \tan^{-1} R\omega C \\ C &= 0.01 \text{ microfarad} \\ f &= 60 \text{ cycles}\end{aligned}$$

In the basic phase-control circuit, Fig. 1, the thyatron cannot be made to behave as a half-wave rectifier for any combination of R_g and C_1 . The curvature of the E_s - I_3 curve is dependent on the value of C because the value of I_3 increases as the value of C increases.⁶

The relationship between the effective phase angle and negative-grid bias E_s is shown in Fig. 7 as the solid curve. T_1 and T_2 were FG57 and 6C5 respectively, R_g

⁶ J. Millman and S. Seely, "Electronics," McGraw-Hill Book Co., New York, N. Y., 1941, p. 457.

was 10^4 ohms, and $C = 0.01$ microfarad. The relationship is approximately linear; especially is it so for phase shifts from 90 to 180 degrees. The author has used this circuit for control purposes, and has found that effective

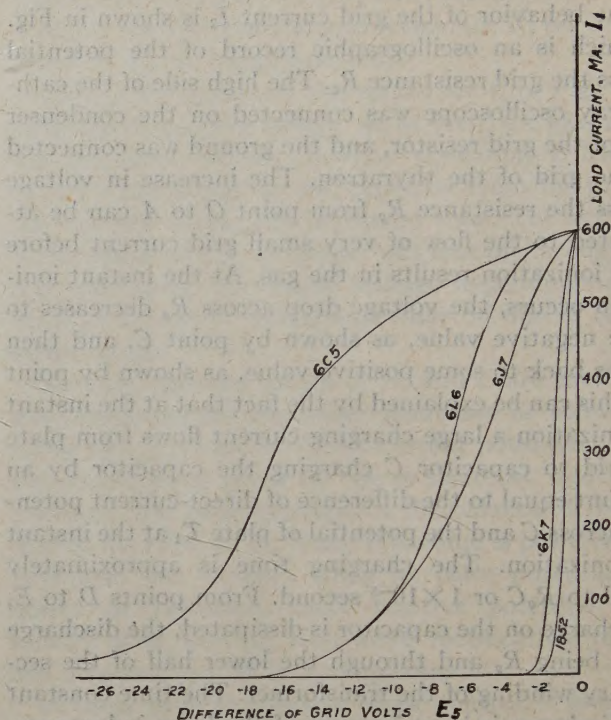


Fig. 8—Effect of $E_g I_o$ characteristics on load current.

$$\begin{aligned}R_g &= 0.1 \text{ megohm} \\ C &= 0.01 \text{ microfarad}\end{aligned}$$

control can be obtained by varying the phase from 90 to 180 degrees.

It is obvious that the degree of control can be varied by careful selection of vacuum tube T_2 . The effect of different tubes is shown graphically in Fig. 8. Note that the abscissa is the "difference of grid voltage." The operating grid bias is determined by the value of capacitor C . For triodes, this voltage is approximately -25 volts, and for pentodes it varies from -67.5 to -90 volts. The screen grids of the pentodes were connected through a proper resistance to the plate.

Corrections

(NOTE: This correction was incorrectly published in the October 1943, issue of the PROCEEDINGS on p. 582.)

It has been brought to the attention of the author, Frederick Emmons Terman, that an error appears in his book *Radio Engineers Handbook*, which has been recently published. This error is in equation (117) which appears on page 216 of the *Handbook*. This particular section of the *Handbook* was reprinted in the April, May, and June, 1943, issues of the PROCEEDINGS under the title of "Network Theory, Filters, and Equalizers." The error in question appears on page 234 of the May, 1943, issue of the PROCEEDINGS in equation (38). In place of reading

$$R_1 = R_I \left(\frac{\alpha - 1}{\alpha + 1} \right)$$

$$R_2 = R_I \left(\frac{2\alpha}{\alpha^2 + 1} \right)$$

it should be

$$R_1 = R_I \left(\frac{\alpha - 1}{\alpha + 1} \right)$$

$$R_2 = R_I \left(\frac{2\alpha}{\alpha^2 - 1} \right)$$

The decimal classification for "Heat-Conduction Problems in Presses Used for Gluing of Wood," by George H. Brown, which appeared in the October, 1943, issue of the PROCEEDINGS on pages 537-548, should read "R590X536" instead of R590XR536.

Norman E. Polster has called the attention of the Editor to an error which appeared in the correspondence section of the PROCEEDINGS for November, 1943. The example

$$V_{00'} = \left[\frac{1/r}{1/r + 1/R} + \frac{1/R - (1/r + 1/R)}{-(1/r + 1/R)} \exp \left(-\frac{t}{RC} - \frac{t}{rc} \right) \right]$$

should read

$$V_{00'} = \left[\frac{1/R}{1/r + 1/R} + \frac{1/R - (1/r + 1/R)}{-(1/r + 1/R)} \exp \left(-\frac{t}{RC} - \frac{t}{rc} \right) \right]$$

Theoretical Limitation to Transconductance in Certain Types of Vacuum Tubes*

J. R. PIERCE†, ASSOCIATE, I.R.E.

Summary—The thermal-velocity distribution of thermionically emitted electrons limits the low-frequency transconductance which can be attained in tubes in whose operation space charge is not important. A relation is developed by means of which this dependence may be evaluated for tubes employing electric and magnetic control. This relation is applied to deflection tubes with electric and magnetic control and to stopping-potential tubes. Magnetic control is shown to be inferior to electric control from the point of view of bandwidth and gain.

I. INTRODUCTION

IN THE operation of the usual negative-grid tube, the varying fields due to space charge play a determining part in control of the electron current. There are, however, several types of vacuum tube in which the varying fields due to space charge do not have an important effect. Such, for example, are deflection tubes, in which a sharply focused electron beam is deflected by electric or magnetic means past an intercepting edge. This type of tube was known as early¹ as 1912. Another example is the "stopping-potential" or "retarding-field" tube in which electrons are turned back or allowed to proceed through changing the potential of a "stopping-potential" grid placed normal to the electron flow. This sort of action was discussed by Carrara² in 1932. Various aspects of such tubes have been discussed in the later literature.

This paper discusses the low-frequency operation of tubes in which the varying effects of space charge are unimportant in the control of electron flow. Its purpose is to express certain limits imposed on the performance of such tubes by the thermal-velocity distribution of electrons leaving the cathode. These are not the only limits to performance, and, indeed, in most actual tubes such factors as electron optical aberration, variation in potential over grids, and contact-potential variations affect the transconductance more than do thermal velocities. Nevertheless, an understanding of the effects of thermal velocities helps in understanding the operation of such tubes and in seeing similarities and differences. Several important points are brought out. For instance, it might be thought that the transconductance of a deflection tube could be increased indefinitely by use of electron-optical means for amplifying the deflection. Such is not the case, and except for aberrations the limiting transconductance of deflection tubes is quite independent of the nature of the fields between the deflection region and the cutoff edge. As another example,

it is shown that from the point of view of gain and bandwidth magnetic control is definitely inferior to electric control for any voltages of operation likely to be encountered.

II. LIMITATIONS AND TERMINOLOGY

This paper deals with the low-frequency operation, or operation in which the transit times are short compared with the period of the applied signal, of any vacuum tubes in which space charge does not play an important role in the control or sorting regions.

By control region is meant the region in which the velocity of the electron stream is influenced by the control fields. This might be the region of deflection in a deflection tube.

By the region of sorting is meant the region in which electrons are sorted or divided into two streams according to their direction or speed. One of these streams goes to the output electrode of the tube, and the other is usually wasted on some other electrode not connected to the output circuit. The sorting region might be the region between the deflecting plates and the cutoff edge in a deflection tube.

Sometimes the control and sorting regions may be the same, as in what may be called a stopping-potential tube, in which electrons are injected into a retarding field, terminating at the control grid, which acts both as a velocity-controlling and as a sorting space.

One sort of tube with which this memorandum is not concerned may be exemplified by the diode with space-charge-limited current flow. This is a sort of stopping-potential tube in which the electrons leave the thermionic cathode with certain initial velocities. In a diode the sorting region is the region between the thermionic cathode and the potential minimum. There electrons are slowed up. Those having high velocities are able to pass the potential minimum and reach the plate; those with low velocities are returned to the cathode. The control region coincides with this sorting region. However, the fields affecting the velocities of the electrons do not depend solely on the potentials applied to the electrodes, but depend on the current flowing as well. The work to be presented applies as a whole only when space-charge effects are negligible, so that the fields in the control region may be regarded as functions of the control voltage or current only.

In the work presented, many equations are involved, and it is impractical to rewrite all equations in numerical form. Accordingly, the units used will be stated here. Length is measured in centimeters, current in amperes, capacitance in farads, transconductance in mhos. Several constants used are:

* Decimal classification: R139XR262.5. Original manuscript received by the Institute, April 8, 1943; revised manuscript received, May 21, 1943.

† Bell Telephone Laboratories, Inc., New York, N. Y.

¹ Robert H. Goddard, U. S. Patent No. 1,159,209, November 2, 1915. (Application filed, August 1, 1912).

² Nello Carrara, "The detection of microwaves," *PROC. I.R.E.*, vol. 20, pp. 1615-1626; October, 1932.

electronic charge	$e = 1.59 \times 10^{-19}$ coulomb
electronic mass	$m = 9.00 \times 10^{-26}$ gram
Boltzman's constant	$k = 1.37 \times 10^{-23}$ joule per degree
Permittivity of space	$\epsilon_0 = 8.85 \times 10^{-14}$ farad per centimeter
Permeability of space	$\mu_0 = 1.257 \times 10^{-8}$ weber per ampere turn centimeter

Two special reduced quantities will be used in measuring velocity and potential

$$u = v(m/2kT)^{1/2}$$

$$\Phi = \phi/kT = 11600\phi/T$$

Here v is velocity in centimeters per second and ϕ is potential in volts. T is the temperature in degrees Kelvin of the thermionic cathode supplying electrons in the vacuum tube under consideration. The units are chosen so that the speed an electron acquires in starting from rest and falling through a potential difference Φ is $u = \sqrt{\Phi}$.

III. GENERAL EXPRESSION FOR TRANSCONDUCTANCE

Consider conditions at a small element of physical space. For this element let us draw a diagram in velocity space u_x, u_y, u_z , shown in Fig. 1. In this diagram S is a surface in velocity space such that all electrons having velocities represented by points to one side of S go to one electrode A and all electrons represented by points lying to the other side of S go to another electrode B .

We can choose arbitrarily the direction in which we consider the current carried by the electrons to flow, as long as all the electrons cross a plane perpendicular to this direction. Let us choose the x direction as the direction of current flow. For electrons leaving a thermionic cathode it has been established^{3,4} that anywhere in the electron stream the portion of the current density in the x direction associated with electrons with velocities lying in the range $du_x du_y du_z$ at u_x and $u^2 = u_x^2 + u_y^2 + u_z^2$ is given by

$$dj = (2/\pi)j_0 u_x e^{-(u^2-\Phi)} du_x du_y du_z. \quad (1)$$

Here Φ is potential measured with respect to the cathode. If we wish to speak of the current crossing an area $dydz$, we may write

$$di = (2/\pi)j_0 u_x e^{-(u^2-\Phi)} du_x du_y du_z dydz. \quad (2)$$

The total current reaching electrode A may then be obtained by integrating (2) over all regions of velocity space in which electrons are present, in the region on the appropriate side of the surface S , and over the cross section of the beam with respect to y and z .

Suppose that in a time dt , all electrons under consideration suffer a velocity change du . Some current which formerly went to A will now go to B . The amount will be that associated with electrons represented by points in velocity space lying in the elementary volume

$$d\gamma = ds du \cos \alpha. \quad (3)$$

Here ds is an element of area of the surface S in velocity space, du is the change in velocity and α is the angle between du and the normal to ds . The change in current

to A corresponding to this change is then

$$di = (2/\pi)j_0 u_x e^{-(u^2-\Phi)} ds du \cos \alpha dydz. \quad (4)$$

1. Electric Control

If the change in velocity in the time dt is due to the application of a field dE , the change in velocity will be in the direction of dE and will have a magnitude given by

$$dv = (e/m)dEdt$$

$$du = (m/2kT)^{1/2} dv = (m/2kT)^{1/2} (e/m)dEdt. \quad (5)$$

The time dt is related to the distance of motion in the x direction, dx .

$$dt = (dx/v_x) = (dx/u_x)(m/2kT)^{1/2}. \quad (6)$$

Using (5) and (6) in (4)

$$di = (e/\pi kT)j_0 e^{-(u^2-\Phi)} ds dE \cos \alpha d\tau. \quad (7)$$

Here $d\tau$ is an element of volume. We shall note that α

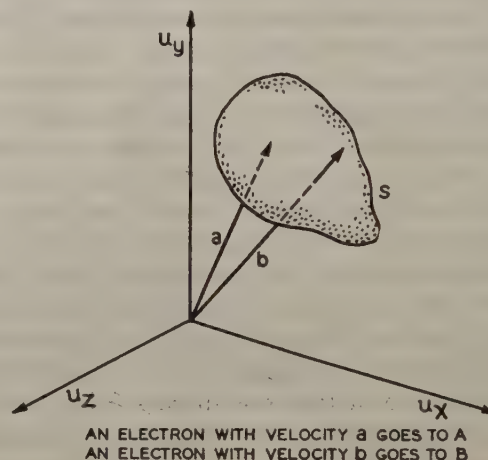


Fig. 1—The sorting surface in velocity space.

is the angle between the field dE and the normal to the surface S .

Relation (7) applies to any sorting type of tube if in the term dE are included all variable fields, both those due directly to changes in control-electrode potential and those due to consequent changes in current and hence in space charge.

In some vacuum tubes the variable fields due to changes in space charge are negligibly small and dE may be taken as the field due to changes in control-electrode potential in the absence of electron flow. If this is so, dE can be related to dV , a voltage increment applied to the control electrode, in terms of the capacitance of the control electrode.

Consider, in the absence of space charge, a tube of force leaving one control electrode, passing through the space which is to be occupied by electron flow, and ending on another electrode. Such a tube of force is shown in Fig. 2. At some point along this tube the cross-sectional area is dA and the electric field is dE . The electric flux is then

$$d\psi = dEdA. \quad (8)$$

This flux is produced by the application of a potential dV between the electrodes on which the tube terminates. Thus the portion of capacitance associated with the part

³ J. R. Pierce, "Limiting current densities in electron beams," *Jour. Appl. Phys.*, vol. 10, pp. 715-723; October, 1939.

⁴ D. B. Langmuir, "Theoretical limitations of cathode-ray tubes," *Proc. I.R.E.*, vol. 25, pp. 977-992; August, 1937.

of an electrode on which the tube terminates is

$$dC = p_0(d\psi/dV). \quad (9)$$

If dw is an elementary length along the tube of force, an elementary volume along the tube is

$$d\tau = dAdw. \quad (10)$$

From (10), (9), and (8)

$$dE = \frac{dCdVdw}{p_0d\tau}. \quad (11)$$

Putting this value in equation (7)

$$di = \frac{ej_0}{\pi kTp_0} \epsilon^{-(u^2-\Phi)} dsdCdw dV \cos \alpha \quad (12)$$

$$dg_m = \frac{di}{dV} = \frac{ej_0}{\pi kTp_0} \epsilon^{-(u^2-\Phi)} dsdCdw \cos \alpha. \quad (13)$$

The transconductance for the whole control space can be obtained by integrating at each point over the sur-

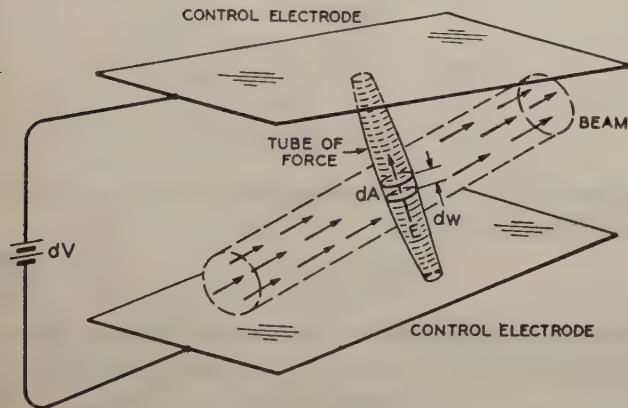


Fig. 2—Control field.

face S in velocity space, along each tube of force connected with an element of capacitance, and over all elements of capacitance. It must be understood that the only portion of the capacitance of a control element which is effective is that associated with tubes of force crossing the electron flow. Capacitance associated with tubes of force which do not cross the flow will be called stray capacitance.

2. Magnetic Control

If a small change in magnetic field dB takes place, an electron in moving a time dt will suffer a change in velocity normal to the change in magnetic field and to the direction of motion, and of magnitude

$$\begin{aligned} dv &= (e/m)vdB \sin \beta dt \\ du &= (m/2kT)^{1/2}dv \\ &= (e/2kT)^{1/2}(e/m)^{1/2}vdB \sin \beta dt. \end{aligned} \quad (14)$$

Here β is the angle between B and u .

Combining (14) with (4) a quantity somewhat analogous to transconductance can be obtained

$$\begin{aligned} dL_m &= di/dB \\ &= j_0(2/\pi)(e/2kT)^{1/2}(e/m)^{1/2}u\epsilon^{-(u^2-\Phi)}dSd\tau \cos \alpha \sin \beta. \end{aligned} \quad (15)$$

There seems little point in reducing this to an expression involving inductance and current rather than B .

As in the case of electric control, the total value of L_m can be obtained by integrating over the surface S in velocity space and over the volume of the control region.

IV. TYPES OF ELECTRON BEAMS

Tubes for operation at low frequencies with negligible space charge will differ depending on the shape and location of the sorting surface S and on the type of electron beam used. Three types of beams are of interest, and these will now be described.

A parallel or unfocused electron beam is one in which no fields have acted on the beam save along one axis, the direction of motion, i.e., the x direction. Conservation of energy tells us that at a point in space at which the potential is Φ , no electrons are present in the region of velocity space.

$$u_x^2 < \Phi. \quad (16)$$

All values of u_y and u_z are permissible. Thus the electron density is other than zero in a region in velocity space

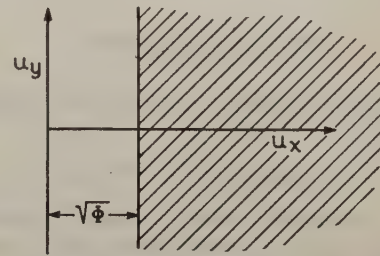


Fig. 3—Parallel beam.

beyond a plane perpendicular to the u_x axis through the point,

$$u_x = \sqrt{\Phi}. \quad (17)$$

This is illustrated in Fig. 3. In using (13) and (15) in the parallel-beam case we must integrate over only those portions of S which lie beyond this plane.

A line-focus beam is one in which fields act in the x direction and one other direction, say, the y direction, but not in the z direction. Conservation of energy tells us concerning the two components of velocity which can be changed by the fields that $u_x^2 + u_y^2 > \Phi$. One possible state of affairs is that in which electron density is other than zero in a region outside the cylinder $u_r^2 = u_x^2 + u_y^2 = \Phi$ and within a dihedral angle whose sides make an angle θ with the $u_x u_z$ plane. This angle θ will be determined by the angular extent of the aperturing system which is used to eliminate widely diverging electrons from the beam. This line-focus case is illustrated in Fig. 4. Line-focus beams do not necessarily fulfill this condition, but it is a limiting condition for which the current density within a given angular range is as high as possible; its use in conjunction with (13) and (15) will give limiting transconductance for line-focus beams.

In the case of point-focus beams, fields can act on the electrons in all three directions. The energy condition which must be fulfilled is then that

$$u_x^2 + u_y^2 + u_z^2 > \Phi. \quad (19)$$

In this case the condition which gives the highest possible

current density is that the density is other than zero in a region outside the sphere

$$u^2 = u_x^2 + u_y^2 + u_z^2 = \Phi \quad (20)$$

and within a cone whose sides make an angle θ with the u_x axis. As in the line-focus case, θ will be determined by the aperturing system. This point-focus case is illustrated in Fig. 5.

When parallel, line-focus, or point-focus beams are referred to henceforward, it will be understood that the

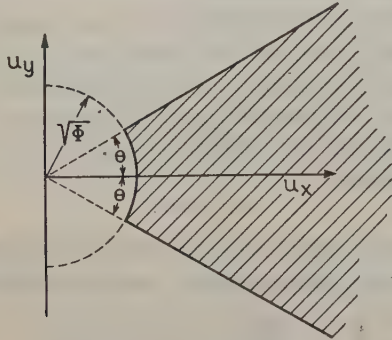


Fig. 4—Line-focus beam.

electron density is other than zero in regions as described above.

V. DEFLECTION TUBES

A form of deflection tube is illustrated in Fig. 6. An electron stream from a cathode diverges, is made parallel by an electron lens l_1 , passes between deflecting plates d and d' , is made convergent by a second lens l_2 , impinges on a cutoff edge placed at its focus, whence part of it travels on to the anode. As the voltage between the deflecting plates is changed, the beam is swept past the cutoff edge and the current to the anode is thus made to vary. The deflection may be brought about through magnetic instead of electric means.

A deflection tube may be defined as one in which in the control region the sorting surface S is a plane in velocity space parallel to the direction of electron motion. This will be taken as the $u_x u_z$ plane.

1. Electric Deflection

For parallel and line-focus cases, the current density is other than zero from $u_x = \sqrt{\Phi}$ to $u_x = \infty$. We shall assume that the potential is constant throughout the region of deflection. Then, only α will vary in the integration with respect to dw and the integral of $\cos \alpha$ will be the beam width W in a direction normal to S . It will be assumed that W is constant in the region of deflection. Under these conditions, the transconductance is given by

$$\begin{aligned} g_m &= WC \frac{ej_0}{\pi kT p_0} e^{\Phi} \int_{-\infty}^{+\infty} \int_{\sqrt{\Phi}}^{\infty} e^{-u_x^2} e^{-u_z^2} du_x du_z \\ &= WC \frac{ej_0}{2kT p_0} e^{\Phi} (1 - \text{erf} \sqrt{\Phi}) \\ \text{erf } x &= \frac{2}{\sqrt{\pi}} \int_0^x e^{-u^2} du. \end{aligned} \quad (21)$$

g_m is given to better than 12 per cent by the approximate form

$$g_m = \frac{ej_0}{2kT p_0} \frac{WC}{\sqrt{\pi \Phi + 1}} \quad (22)$$

The error is about 2 per cent for $\Phi = 5$ and decreases for larger values of Φ .

In the case of a point-focus beam, with the same sort-

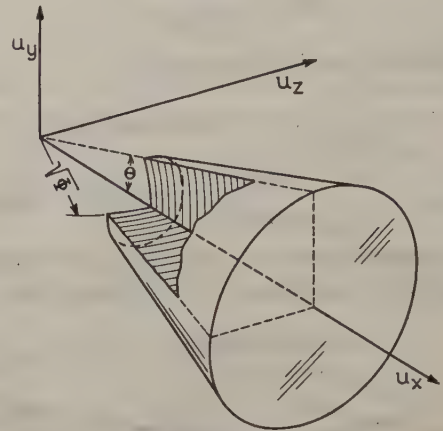


Fig. 5—Point-focus beam.

ing plane, the electron density is other than zero on regions of the $u_x u_y$ plane

$$u_x^2 + u_y^2 = u_r^2 > \Phi \quad (23)$$

$$-\theta < \beta < \theta \quad (24)$$

Here β is the angle with respect to the u_x axis. An appropriate element of area of the plane S is

$$ds = u du d\beta \quad (25)$$

Again we shall assume the potential and the beam width constant, and we shall assume θ also constant throughout the region of deflection. As in the previous

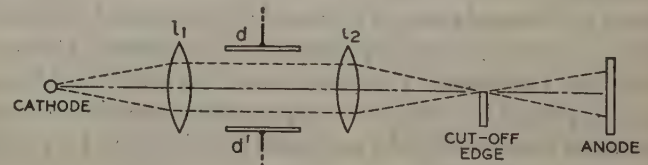


Fig. 6—Deflection tube.

case, $\cos \alpha$ will be taken care of by measuring W normal to S . Integrating to obtain the transconductance,

$$\begin{aligned} g_m &= \int_{-\theta}^{+\theta} \int_{\sqrt{\Phi}}^{\infty} \frac{ej_0}{\sqrt{\Phi} \pi kT p_0} u e^{-(u^2 - \Phi)} du d\beta dC dw \\ &= \frac{ej_0 WC \theta}{\pi kT p_0} \end{aligned} \quad (26)$$

This expression seems independent of Φ . However, for a given current density, θ is a function of Φ and is smaller the larger Φ is.

In the point-focus case it may be desirable to use a beam of circular cross section, so that the beam will be of variable width. In this case the mean width should be used as W . If the beam is converging in the control region there will be a variation of both W and θ , and a mean value of $W\theta$ may be used. Variations in current

density over the cross section of the beam also mean variations of θ , and may be taken into account by using a mean value of $W\theta$.

2. Magnetic Deflection

In the case of magnetic-control fields, the only possible sort of tube is the deflection tube, for the magnitude of the velocity cannot be altered by the control field.

Control will be most effective when the magnetic field is perpendicular to the direction of motion, the x direction, and parallel to the sorting surface. In this case, along the sorting surface $v \sin \beta = v_x$, $\cos \alpha = 1$. For parallel and line-focus cases, the current will be other than zero from $u_x = \Phi$ to $u_x = \infty$. It will be assumed that dB and Φ are constant throughout the region of deflection, and that τ is the total volume. Under these conditions

$$L_m = j_0 \tau (2/\pi) (e/2kT)^{1/2} (e/m)^{1/2} j_0 \tau \epsilon^\Phi \int_{-\infty}^{+\infty} \int_{\sqrt{\Phi}}^{\infty} u_x \epsilon^{-u_x^2} \epsilon^{-u_z^2} du_x du_z = (1/\pi)^{1/2} (e/2kT)^{1/2} (e/m)^{1/2} j_0 \tau. \quad (27)$$

For the point-focus case

$$L_m = (2/\pi) (e/2kT)^{1/2} (e/m)^{1/2} j_0 \tau \epsilon^\Phi \int_{-\theta}^{\theta} \int_{\sqrt{\Phi}}^{\infty} u^2 \epsilon^{-u^2} \cos \theta d\theta du = (2/\pi) (e/2kT)^{1/2} (e/m)^{1/2} j_0 \tau [\sqrt{\Phi} + (\sqrt{\pi}/2) \epsilon^\Phi (1 - \operatorname{erf} \Phi)] \sin \theta. \quad (28)$$

For reasonably large values of Φ

$$L_m = (2/\pi) (e/2kT)^{1/2} (e/m)^{1/2} j_0 \tau [\sqrt{\Phi} + 1/2\sqrt{\Phi}] \sin \theta. \quad (29)$$

VI. STOPPING-POTENTIAL TUBES

A type of stopping-potential tube is shown in Fig. 7. In this tube the electrons are accelerated from the cath-

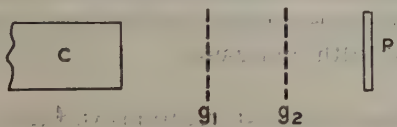


Fig. 7—Stopping-potential tube.

ode by g_1 , and slowed down and controlled between g_1 and g_2 . Varying the potential of g_2 determines how many electrons can get past g_2 and reach the plate P .

In this type of tube, the sorting surface S is a plane perpendicular to the direction of electron motion. The sorting electrode, such as g_2 in Fig. 7, is assumed to be at a negative potential $-\Phi_0$ with respect to the cathode. In this case an electron must have an x component of velocity greater than that specified by the potential in order to pass the sorting electrode, and such, in fact, that at $\Phi = -\Phi_0$, the x velocity must be equal to zero. This means that the sorting surface S will be a plane in velocity space perpendicular to the u_x axis at a position $u_x = \sqrt{\Phi + \Phi_0}$. It will be assumed that the applied field acts normal to S , so that $\cos \alpha$ is unity.

For the parallel case, g_m will be

$$g_m = \frac{ej_0 WC}{\pi kT p_0} \epsilon^{-\Phi_0} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \epsilon^{-u_y^2} \epsilon^{-u_z^2} du_y du_z = \frac{ej_0 WC}{kT p_0} \epsilon^{-\Phi_0}. \quad (30)$$

Here W is the width of the beam in the control region perpendicular to S , or in the direction of motion, u_x .

For the line-focus case there is a restriction that the only portion of the surfaces S over which the integration should be carried out is that lying within a dihedral angle 2θ , giving

$$g_m = \frac{ej_0 WC}{\pi kT p_0} \epsilon^{-\Phi_0} \int_{-\infty}^{+\infty} \int_{-\sqrt{\Phi+\Phi_0} \tan \theta}^{+\sqrt{\Phi+\Phi_0} \tan \theta} \epsilon^{-u_y^2} \epsilon^{-u_z^2} du_y du_z = \frac{ej_0 WC}{kT p_0} \epsilon^{-\Phi_0} \operatorname{erf}(\sqrt{\Phi + \Phi_0} \tan \theta). \quad (31)$$

For the point-focus case, the only portion of the surface S over which the integration should be carried out is that lying within a cone of half-peak angle θ . It seems advisable to use a quantity u_p such that

$$u_p^2 = u_y^2 + u_z^2 \\ ds = 2\pi u_p du_p.$$

The transconductance will then be given by

$$g_m = \frac{2ej_0 WC}{kT p_0} \epsilon^{-\Phi_0} \int_0^{\sqrt{\Phi+\Phi_0} \tan \theta} \epsilon^{-u_p^2} u_p du_p = \frac{ej_0 WC}{kT p_0} \epsilon (1 - \epsilon^{-(\Phi+\Phi_0) \tan^2 \theta}). \quad (32)$$

It is seen from (29) and (30) that the transconductance is less for point-focus and line-focus beams than for a parallel beam if θ is less than $\pi/2$.

VII. STOPPING-POTENTIAL TUBES WITH POSITIVE STOPPING-POTENTIAL ELECTRODES

In the case of point-focus and line-focus beams, it is possible to operate the stopping-potential electrode at a positive potential Φ_0 with respect to the cathode. This may occur, for instance, if a beam is focused on a gap between two widely spaced negative control wires, the central region between the wires being positive because of neighboring positive electrodes. In this case, the sorting plane S is at a position in velocity space $u_x = \sqrt{\Phi - \Phi_0}$ from the origin.

In the line-focus case, the only portion of the surface S which should be integrated over is that lying outside of a dihedral angle whose sides cut the surface $u_x^2 + u_y^2 = \Phi$ at $u_y = \sqrt{\Phi - (\Phi - \Phi_0)} = \sqrt{\Phi_0}$ and within the angle θ . The transconductance will then be given by

$$g_m = \frac{2ej_0 WC}{\pi kT p_0} \epsilon^{\Phi_0} \int_{-\infty}^{+\infty} \int_{\Phi_0}^{\sqrt{\Phi-\Phi_0} \tan \theta} \epsilon^{-u_x^2} \epsilon^{-u_y^2} du_x du_y = \frac{ej_0 WC}{kT p_0} \epsilon^{\Phi_0} (\operatorname{erf} \sqrt{\Phi - \Phi_0} \tan \theta - \operatorname{erf} \sqrt{\Phi_0}), \quad (33)$$

For $\theta = \pi/2$, g_m is given to within better than 12 per cent by

$$g_m = \frac{ej_0 WC}{kT p_0 \sqrt{\pi \Phi_0 + 1}}. \quad (34)$$

It may be seen from (33) that in the line-focus case the transconductance is a maximum for $\Phi_0 = 0$.

In the point-focus case, the integration should be over the part of the plane S for which $\sqrt{\Phi - \Phi_0} \tan \theta > u_p > \sqrt{\Phi_0}$. g_m is thus given by

$$g_m = \frac{2Ej_0WC}{kTp_0} e^{\Phi} \int_{\sqrt{\Phi_0}}^{\sqrt{\Phi - \Phi_0} \tan \theta} e^{-u_p^2} u_p du_p \\ = \frac{ej_0WC}{kTp_0} (1 - e^{-(\Phi - \Phi_0) \tan^2 \theta}). \quad (35)$$

It is seen that in the case of the point-focus beam that when $\theta = \pi/2$, the transconductance is constant for all positive values of Φ .

VIII. A SPECIAL STOPPING-POTENTIAL TUBE

Tube designs can be imagined in which the surface S is a cylinder or sphere of radius $\sqrt{\Phi}$ about the origin. This can be the case, for instance, in a tube in which a line-focus or point-focus beam is acted upon in a region of narrow cross section, allowed to diverge, and then made parallel in a sorting region of wide cross section, as illustrated in Fig. 8. Here a beam from a cathode C

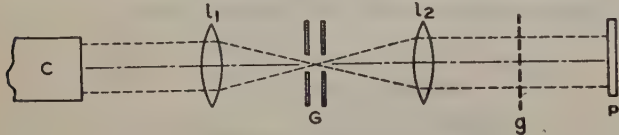


Fig. 8—Special stopping-potential tube.

converges and passes through a control gap G , where its velocity is varied. After diverging and increasing in size it is made parallel by electron lens l and sorted at stopping-potential grid g . Thereafter, the remainder of the beam strikes the output electrode P .

It will be assumed that the lines of force act along the x axis. Thus α will be the angle with respect to the u_x axis.

In the line-focus case, it is convenient to use a quantity $u_r^2 = u_x^2 + u_y^2$.

Along the surface S , u_r is constant, and $ds = u_r d\alpha dz = \sqrt{\Phi} d\alpha dz$.

Accordingly, the transconductance will be

$$g_m = \frac{ej_0WC}{\pi kTp_0} \sqrt{\Phi} \int_{-\infty}^{+\infty} \int_{-\theta}^{+\theta} e^{-u_x^2} \cos \alpha du_x d\alpha \\ = \frac{2j_0WC}{\sqrt{\pi} kTp_0} \sqrt{\Phi} \sin \theta. \quad (36)$$

It is apparent that this transconductance may be considerably higher than that for a conventional stopping-potential tube.

In the point-focus case, a quantity u will be used which is constant over the surface S , $u^2 = u_x^2 + u_y^2 + u_z^2 = \Phi$.

The element of area will be

$$ds = 2\pi u^2 \sin \alpha d\alpha = 2\pi \Phi \sin \alpha d\alpha.$$

Accordingly, the transconductance will be

$$g_m = \frac{2ej_0WC}{kTp_0} \Phi \int_0^\theta \sin \alpha \cos \alpha d\alpha \\ = \frac{ej_0WC}{kTp_0} \Phi \sin^2 \theta. \quad (37)$$

This transconductance also is considerably higher than that of a conventional stopping-potential tube.

IX. COMPARISON OF ELECTRIC AND MAGNETIC CONTROL

From the point of view of amplification over a wide band of frequencies, the determining factor is the amount of energy stored in the control field for a given change in current. For instance, if the input capacitance of an electrically controlled tube is doubled, the stored energy for a given input voltage is doubled and the bandwidth over which a given input impedance can be maintained is halved. An important figure of merit of a tube is thus the change in output current squared for unit stored energy in the control field. For an electrically controlled tube this is

$$i^2 = 2g_m^2/C. \quad (38)$$

For a magnetically controlled tube this change is

$$i^2 = 2L_m^2 \mu_0 / \tau. \quad (39)$$

The ratio of (38) and (39) gives the relative merits of electric and magnetic control from the point of view of bandwidth and gain. This ratio R is

$$R = (g_m/L_m)^2 \tau / \mu_0 C. \quad (40)$$

For a line-focus deflection tube and for values of Φ large enough so that approximate forms may be used

$$R = (mc^2/2e\phi). \quad (41)$$

Comparison for the point-focus case leads to the same expression, save for an additional factor $(\theta/\sin \theta)^2$, favorable to electric control.⁵

The quantity $mc^2/2e$ corresponds to a potential of 255,000 volts. The nonrelativistic nature of this work makes it completely inapplicable at that potential. It may be safely concluded, however, that for reasonable potentials electric control will give more gain than magnetic control. Considering that electric control is most effective when applied longitudinally, the case for magnetic control seems almost hopeless from the point of view of bandwidth and gain.

X. DISCUSSION AND NUMERICAL EXAMPLES

Examining (21), (26), (30), (31), (32), (33), (35), (36), and (37), it may be seen that for a given capacitance, transconductance increases as cathode-current density j_0 is increased and as the width W of the control region is increased. The desirability of high cathode current density is well known, and in the case of negligible space charge quite obvious; twice the current density, twice the output current. The gain through increasing W may be illusory; the larger W , the less the total current must be if space charge is to be avoided. In deflection tubes, an increase in W may be made allowable without other

⁵ The comparison can be made more directly as follows: Consider a control field of constant intensity over a unit volume. Imagine an electron moving with a velocity specified by the potential ϕ . The least electric field strength which can produce unit force is $E = (1/e)$. The stored energy is $W_1 = p_0/e^2$. The least magnetic field that can produce unit force is $B = (1/e)[2(e/m)\phi]^{-1/2}$. The stored energy is $W_2 = (1/\mu_0)(1/e^2)[2(e/m)\phi]^{-1}$. Thus the ratio of stored energies for the same control effect is $R = W_2/W_1 = m/2p_0\mu_0 e\phi = mc^2/2e\phi$.

loss if the angular spread of the beam is reduced, thus reducing the total current flow.

When potential enters the various expressions, low potentials appear to be best. This is not conclusive, as higher currents can be used at higher potentials. Thus, for a given tube the current density j_0 increases as the $3/2$ power of the voltage, giving a net increase in transconductance for any of the types of tube discussed.

Enlarging the control region perpendicular to W increases both transconductance and capacitance, and results in a gain in their ratio only through reduction of the proportion of useless capacitance associated with edge effects.

It is of interest to substitute plausible figures into the various equations derived. For a deflection tube, from (22), assuming

$$\begin{aligned} j_0 &= 0.05 \text{ ampere per square centimeter} \\ T &= 1160 \text{ degrees Kelvin} \\ W &= 0.25 \text{ centimeter} \\ C &= 1 \times 10^{-12} \text{ farad} \\ \phi &= 50 \text{ volts } (\Phi = 500) \\ g_m &= 16,800 \times 10^{-6} \text{ mho} \end{aligned}$$

For a stopping-potential tube with a parallel beam, from (30), assuming

$$\begin{aligned} j_0 &= 0.05 \text{ ampere per square centimeter} \\ T &= 1160 \text{ degrees Kelvin} \\ W &= 0.25 \text{ centimeter} \\ C &= 0.1 \times 10^{-12} \text{ farad} \\ \epsilon^{-\Phi} &= 0.5 \\ g_m &= 70,500 \times 10^{-6} \text{ mho} \end{aligned}$$

For the special tube discussed in Section VIII, from (37), assuming

$$\begin{aligned} j_0 &= 0.05 \text{ ampere per square centimeter} \\ T &= 1160 \text{ degrees Kelvin} \\ W &= 0.1 \text{ centimeter} \\ C &= 0.1 \times 10^{-12} \text{ farad} \\ \phi &= 100 \text{ volts } (\Phi = 1000) \\ \sin \theta &= 0.1 \\ g_m &= 563,000 \times 10^{-6} \text{ mho} \end{aligned}$$

Of course, such startling transconductances will not be attained in actual tubes. The transconductances calculated are limiting transconductances. This does not mean that the expressions are inexact, but only that the optimum conditions assumed are not attained in practical tubes. The actual transconductance falls short of the limiting transconductance for the following reasons:

(1) Much of the capacitance in actual tubes is stray capacitance, contributing nothing to the control of the beam.

(2) The assumptions as to the portion of velocity space occupied by electrons, made in Section III, are optimistic.

(3) Because of aberration, misalignment, variation of contact potential over electrodes, and variation in potential over grids, the location and shape of sorting surface S will vary throughout the beam. When this is so the optimum location of the surface may be attained at only a few points in the flow, and at other points the surface S will lie in regions of low or zero current density.

Reason (3) above probably is most important in accounting for the inferior performance of actual tubes. All the defects mentioned above are subject to reduction in some degree.

Neutralization of Screen-Grid Tubes to Improve the Stability of Intermediate-Frequency Amplifiers*

C. A. HULTBERG†, MEMBER, I.R.E.

Summary—By a simple analysis it is shown that the grid-plate reaction in a screen-grid amplifier stage may be neutralized. This is accomplished by injecting into the screen circuit a small voltage opposite in phase to the plate voltage.

Practical means for accomplishing this injection are described and a few of the obvious limitations are outlined. Even imperfect neutralization is claimed to be advantageous in improving the operating characteristics of high-gain—narrow-pass-band amplifiers.

For numerous applications it is felt that the increased stability obtainable more than justifies the inclusion of the additional circuit components required.

THE CONVENTIONAL intermediate-frequency amplifier employing screen-grid tubes is capable of very high gain and may be designed to provide either a broad pass band or a very sharp, highly selec-

tive narrow pass band. In most cases it is desirable to have the gain adjustable by varying the grid bias either manually or by means of automatic gain control, more commonly referred to as automatic volume control.

For low-gain intermediate-frequency stages of the wide-pass-band type the reaction effect between the plate and grid circuits can usually be neglected with impunity.

When the stage gain is high, and especially if the intermediate-frequency amplifier is designed for a very narrow pass band, the plate-grid reaction (commonly referred to as the Miller effect) can no longer be neglected safely. To do so usually results in regeneration, instability, or even oscillation. In addition if the gain is variable, there is a pronounced frequency shift as the gain is varied.

The grid input impedance of a vacuum tube with a

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† Dominion Electrohome Industries, Ltd., Kitchener, Ontario, Canada.

load in the plate circuit is different from the grid input impedance with zero plate load. This is known as the Miller effect. If the load in the plate circuit is a pure resistance the effect is to add a pure capacitive susceptance from grid to cathode. If the plate load is a pure reactance, the effect is to add a pure conductance from grid to cathode. This conductance will be positive if the plate load is capacitive and it will be negative if the plate load is inductive. It is often more convenient to express the susceptance and conductance as equivalent shunt capacitance and resistance.

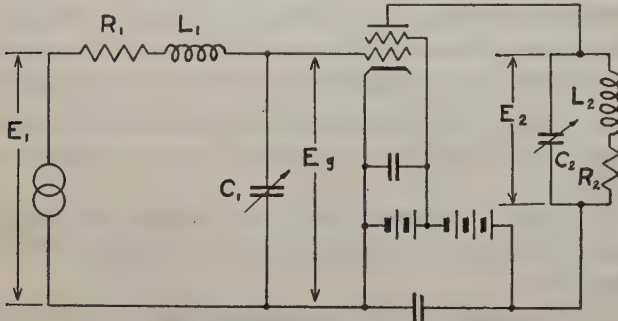


Fig. 1—Circuit of screen-grid tube for demonstrating the Miller effect.

The complete derivation of the input impedance of a vacuum tube with a load in the plate circuit, in the case of a triode, has been given by Terman,¹ who states:

$$\text{input resistance} = R_g = \frac{-1/\omega C_{gp}}{A \sin \theta} \quad (1)$$

$$\text{input capacitance} = C_g = C_{gf} + C_{gs}(1 + A \cos \theta). \quad (2)$$

In the above

C_{gf} = grid-cathode tube capacitance

C_{gs} = grid-plate tube capacitance

$A = E_p/E_g$ = effective grid-plate voltage gain

θ = angle by which voltage across load impedance leads equivalent voltage acting in plate circuit (θ positive for inductive load impedance).

For a screen-grid tube with screen and cathode circuits well by-passed (1) above holds as written; (2) will have one term added as follows:

$$C_g = C_{gf} + C_{gs} + C_{gp}(1 + A \cos \theta) \quad (3)$$

where C_{gp} is the grid-screen tube capacitance.

In Fig. 1 is shown a single-stage amplifier, with the direct-current grid bias omitted for simplicity. E_1 represents the voltage introduced into the tuned input circuit L_1C_1 (with $Q_1 = \omega L_1/R_1$). If we neglect the Miller effect, maximum gain occurs when both the input and output circuits are resonated to the frequency of the voltage E_1 .

If we resonate the input circuit by adjusting C_1 with C_2 short-circuited and then remove the short circuit on C_2 the Miller effect can be demonstrated easily. When C_2 is adjusted for exact resonance for the plate circuit, the impedance $L_2C_2R_2$ looks like a pure resistance. Instead of a grid-tuning capacitance of $C_1 + C_{gf} + C_{gs} + C_{gp}$ which occurred when C_2 was short-circuited, we now

have a grid capacitance of $C_1 + C_{gf} + C_{gs} + C_{gp}(1 + A)$. This indicates that the grid circuit will be tuned to a frequency below resonance. If C_1 is now readjusted for resonance by decreasing C_1 by an amount equal to AC_{gp} the over-all gain will increase.

If we now detune the plate circuit so that A remains high) a negative conductance will appear across C_1 making the apparent Q of the input circuit rise. If A is very high and the normal Q of the input circuit is high also, it is quite likely that oscillation will take place.

Let us now refer to Fig. 2 where the disposition of the various voltages and capacitances of interest in a screen-grid tube are shown. The plate voltage E_p can be expressed as

$$E_p = -A(\cos \theta + j \sin \theta)E_g. \quad (4)$$

We will next introduce into the screen circuit a voltage that is a fraction of E_p and opposite in phase; this yields

$$E_s = kA(\cos \theta + j \sin \theta)E_g. \quad (5)$$

Equations (1) and (3) can be converted to equivalent susceptances and conductances. If we do this and combine the expressions we find that the total grid admittance is

$$Y_g = j\omega\{C_{gf} + C_{gs} + C_{gp}[1 + A(\cos \theta + j \sin \theta)]\}. \quad (6)$$

If we assign the value zero to A in (6), we obtain

$$Y_g' = j\omega(C_{gf} + C_{gs} + C_{gp}). \quad (7)$$

This is the grid admittance corresponding to perfect neutralization. Let us now inject the value of screen voltage called for in (5) above, and set up the equivalent grid admittance; this gives

$$Y_g'' = j\omega\{C_{gf} + C_{gs}[1 - kA(\cos \theta + j \sin \theta)] + C_{gp}[1 + A(\cos \theta + j \sin \theta)]\}. \quad (8)$$

Equating (7) and (8) we get

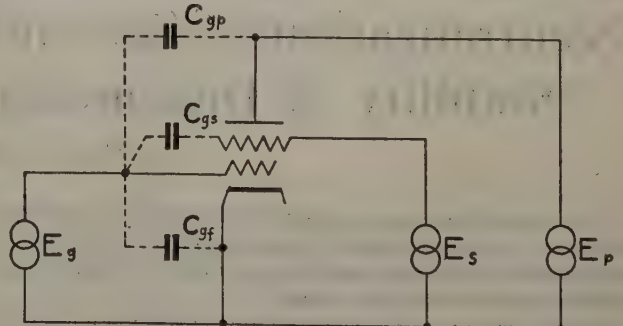


Fig. 2—Equivalent simplified circuit of vacuum tube with capacitive coupling between electrodes.

$$C_{gs}[1 - kA(\cos \theta + j \sin \theta)] - C_{gs} = -C_{gp}[1 + A(\cos \theta + j \sin \theta)] + C_{gp}. \quad (9)$$

Solving for k we obtain

$$k = C_{gp}/C_{gs}. \quad (10)$$

This value of k is seen to be independent of the amplification A and the phase angle θ . Figs. 3, 4, and 5 illustrate practical methods of injecting the required voltage into the screen circuit.

PRACTICAL APPLICATIONS AND LIMITATIONS

In Fig. 3, $L_1 \cdots L_2$ represents a conventional intermediate-frequency transformer. A third winding of

¹ F. E. Terman, "Radio Engineering," second edition, McGraw-Hill Book Co., New York, N. Y., 1937; pp. 231-233.

very few turns as closely coupled to L_1 as possible provides very close to an impedanceless generator in series with the screen circuit. By connecting this winding with proper polarity with respect to L_1 nearly perfect neutralization is easily obtained experimentally. (Since the transformer is not an ideal transformer, the phase shift between primary and secondary will not be exactly 180 degrees but will depart therefrom by approximately $1/Q$ radians.)

In an experimental 2-stage amplifier operating at 455 kilocycles, set up under the author's direction, a single turn wound over the top of a universal wound coil used as L_1 reduced the frequency shift of the total amplifier for a given gain change from a value of 2.3 kilocycles to a value less than 200 cycles. Before L_3 was added to the intermediate-frequency transformers, stage alignment was very difficult because of a pronounced tendency to oscillate during alignment. This effect was practically absent with L_3 in use.

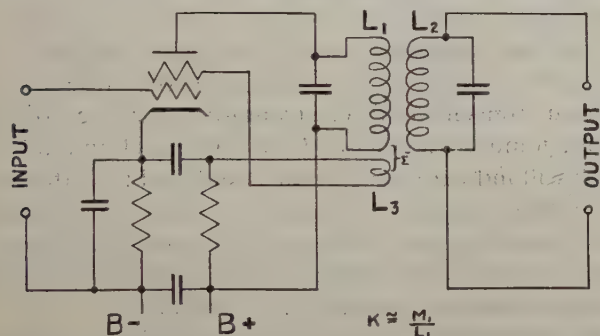


Fig. 3—Inductive method of neutralization of feedback.

Since the grid-screen and grid-plate capacitances of production vacuum tubes are subject to considerable variation, the best neutralization cannot be obtained by a fixed value of coupling between L_1 and L_3 . However a major improvement in stability is easily secured with normal production limits on the position of, and number of turns in, L_3 . The reduction so obtained will leave a residual reaction that will in general be between $1/5$ and $1/25$ of the reaction obtained without neutralization, without resorting to the use of preselected vacuum tubes. The advantage of much less frequency shift with automatic frequency control or manual gain control, plus greater ease of production alignment, is very noticeable when several narrow-pass-band stages are cascaded.

For laboratory equipment or specialized applications it would, of course, be possible to arrange the circuit so that the amount of voltage injected into the screen circuit could be varied for minimum reaction.

For high-frequency applications, where the inductance of L_3 might be detrimental, the circuits shown in Figs. 4 or 5 can be employed. In Fig. 4, and capacitor C_4 should preferably be larger than C_3 . For perfect neutralization the ratio of C_2/C_3 should be made equal to $k(=C_b/C_a)$. In addition, the values of R_2 and R_3 should be several times the capacitive reactance of C_3 .

If the plate and screen circuits are operated at identical direct-current potentials, the simplified circuit of Fig. 5 applies, R_2 should be several times the reactance of C_3 of course, and C_2/C_3 should again equal k .

If one of the elements used to produce the feedback ratio is variable, such as C_2 in Figs. 4 or 5, perfect neutralization is possible at only one frequency. If the circuit is tuned by varying the inductance however, with C_2 and C_3 fixed, a variable frequency neutralized amplifier may be built.

There are, undoubtedly, many who have studied

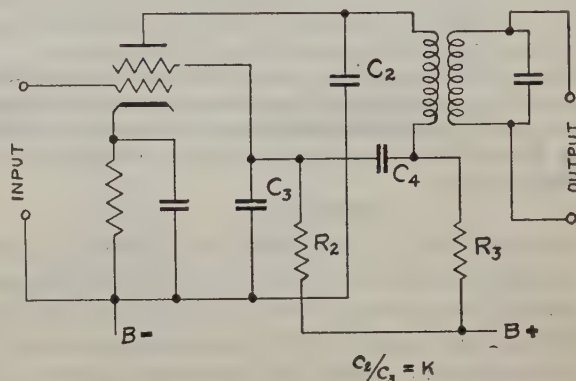


Fig. 4—Capacitive method of neutralization of feedback.

similar projects and papers have been printed describing their work. If proper credit has not been given, it is because the author is not sure to whom the credit is due. Since preparing this paper, it has been brought to the writer's attention that descriptions of the practical methods shown have been covered in the patent literature.

Hazeltine² published an historic paper which opened

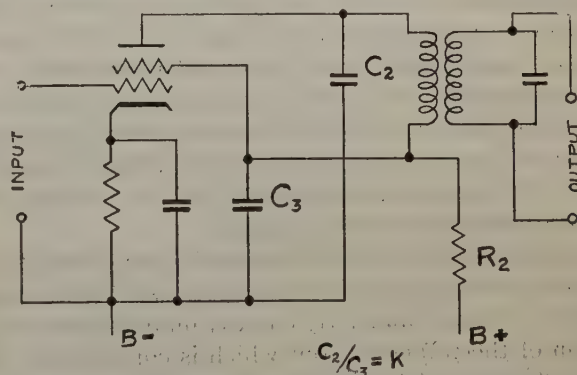


Fig. 5—Simplified capacitive method of neutralization of feedback with screen and plate voltage. Supply at same potential.

up the entire field of neutralization, at a time when screen-grid tubes were not available. The original screen-grid tube, by virtue of its low grid-plate capacitance, was intended to eliminate the need for neutralization. Subsequent improvement in tubes and circuits has brought about such high possible gain levels that even the small grid-plate capacitances again provide insufficient reaction to make the application of Hazeltine's principles advantageous.

² L. A. Hazeltine, "Tuned radio frequency amplification with neutralization of capacity coupling," *Proc. Radio Club Amer.*, vol. 2, March, 1923; and *QST*, vol. 7, pp. 7-12; April, 1923.

The Principle of Reciprocity in Antenna Theory*

M. S. NEIMAN†, MEMBER, I.R.E.

Summary—The reciprocity theorem is applied to transmitting and receiving antenna systems in order to establish several important relationships. Formulas are deduced which establish a relation between the receiving current and power of any given antenna and the field intensity of the arriving waves, all the parameters entering into the formulas being the parameters of the same antenna when it is used as a transmitting antenna.

It is shown that, in the case of strong interference, (1) the highest possible directivity is of importance both in the transmitting and in the receiving antennas and (2) the efficiency and the coefficient of exploitation of the receiving antenna are of no importance.

In the case of low interference, it was found that, (1) the directivities of both the receiving and transmitting antennas are of equal importance and (2) the efficiency and coefficient of exploitation of the receiving antenna are just as important as the efficiency of the transmitting antenna.

INTRODUCTION

THE principle of reciprocity was formulated and established some time ago.¹⁻⁵ As we shall demonstrate, this principle proves to be a powerful tool of investigation, establishing a far-reaching analogy in the performance of receiving and transmitting antennas.

The reciprocity principle may have two lines of application to antenna theory. First, it establishes a simple relation between the properties of transmitting and receiving antennas, which permits a deduction of receiving-antennas properties from those of the transmitting antennas, and vice versa. Second, it establishes an interchangeability in the performance of receiving and transmitting antennas. This means that all the differences in the construction of transmitting and receiving antennas, if they are legitimate, may be based either upon stipulations in the statement of the principle, or upon special conditions, and requirements in antenna performance which do not fit into that statement. Thus in antenna design the reciprocity principle yields a criterion for the evaluation and justification of specific comparative peculiarities in the make-up of receiving and transmitting antennas.

In what follows we shall formulate the principle of reciprocity in its relation to the systems which radiate and absorb electromagnetic energy, omitting the justification of the principle itself which is contained in the works of Sommerfeld and Sveshnikova. After that, we

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† Radio Division, Communication Department, Government Purchasing Commission, U.S.S.R. in the U.S.A., Washington, D. C.

¹ John R. Carson, "A generalization of the reciprocity theorem," *Bell Sys. Tech. Jour.*, vol. 3, pp. 393-399; July, 1924.

² John R. Carson, "Reciprocal theorems in radio communication," *Proc. I.R.E.*, vol. 17, pp. 952-957; June, 1929.

³ A. Sommerfeld, "Das Reziprozitäts-theorem in der drahtlosen Telegraphie," *Jahr. der drahtlosen Teleg. und Teleph.*, vol. 26, S. 93, 1925.

⁴ M. P. Sveshnikova, "The reciprocity theorem in electrodynamics and radiotelegraphy," *Jour. Russian Physico-Chemical Assoc.*, p. 453, 1927.

⁵ Stuart Ballantine, "Reciprocity in electromagnetic, mechanical, acoustical, and interconnected systems," *Proc. I.R.E.*, vol. 17, pp. 929-952; June, 1929.

shall deduce the corollaries to the principle of reciprocity along both of the already mentioned lines of application.

Since the theory of transmitting antennas has been more thoroughly developed and better investigated than the theory of receiving antennas, we shall conduct our discussion in the sense of securing the properties and justifying the peculiarities of receiving antenna construction, assuming the properties of transmitting antennas as given and known.

STATEMENT OF THE RECIPROCITY THEOREM

Let us assume two antennas I and II, which may consist of any combination of conductors, semiconductors, and insulators and may also contain any desired combinations of lumped impedances. Let us mark, on the wires of each of the antennas one arbitrary point, point M_1 on antenna I and point M_2 on antenna II. We can now perform mentally two experiments:

1. Let us apply at the point M_1 of the antenna I an external concentrated electromotive force e_1 of frequency f and at the point M_2 of antenna II an ammeter which will indicate the current I_2 induced by antenna I.
2. Let us apply at the point M_2 an external concentrated electromotive force e_2 of the same frequency f , and at point M_1 of antenna I, an ammeter which will show the current I_1 induced by antenna II.

The electromotive forces and currents in question are shown in Table I where the direction of energy flow is indicated by arrows.

TABLE I

	Antenna I	Antenna II
First experiment.....	e_1 →	I_2
Second experiment.....	I_1 ←	e_2

Let us emphasize that points M_1 and M_2 are arbitrary but are the same for both experiments.

It is assumed that the internal impedances of the generators of the electromotive forces e_1 and e_2 as well as the impedances of the ammeters measuring the currents I_1 and I_2 are equal to zero. It is easy to see that this assumption in no way restricts the generality of the cases since when impedances are present they can be considered as a component part of the antenna.

The principle of reciprocity may be formulated as follows: Current I_2 induced in antenna II from antenna I, excited by the electromotive force e_1 , is to this electromotive force e_1 , as current I_1 induced in antenna I from antenna II excited by the electromotive force e_2 is to that electromotive force e_2 , i.e.,

$$I_2/e_1 = I_1/e_2. \quad (1)$$

It is understood that the arrangement of the antennas I and II and the structure of the medium about both antennas are absolutely arbitrary in all respects but one. Namely, the electromagnetic laws which govern

the phenomena must be linear in the sense of the independence of these laws from the amplitude of oscillations. In other words the following equalities must hold true:

$$\left. \begin{aligned} I_2 &= A \cdot e_1 \\ I_1 &= B \cdot e_2 \end{aligned} \right\} \quad (2)$$

where A and B are constants independent of e_1 and e_2 . Comparing (1) and (2) we see that the principle of reciprocity is expressed by the equality $A=B$. This last equality holds true for passive linear four-terminal networks of which the system between the terminals of the two antennas is an example.

FUNDAMENTAL FORMULAS

Let us assume that the distance between antennas I and II is quite large by comparison with the transmitted wavelengths and the dimensions of the antennas. As seen from the application of the reciprocity theorem to the propagation of electromagnetic waves, the path of a ray going from antenna I to antenna II and that of a ray going from antenna II to antenna I coincide in outline. Furthermore, the angles of rotation of the polarization plane are the same for both rays.⁶ Therefore, the length of the path for both rays is the same and the angle between the polarization planes of the sent and of the received rays are identical for both antennas. The proof of these well-known propositions is beyond the scope of this article.

Let us consider the coefficient of directivity D of antenna I in the direction of the ray going toward antenna II, for the case when antenna I is transmitting.

As we know from the theory of transmitting antennas⁷ $D_1 = (30c^2 r^2 E_2^2 / I_{01}^2 R_{01})$.

Here E_2 = the amplitude of the field intensity about antenna II,

R_{01} = the radiation resistance of antenna I when transmitting referred to the current I_{01} flowing at the point of application of the electromotive force e_1 , expressed in ohms.

Further, $I_{01} = e_1 / Z_{01}$, where Z_{01} is the complex impedance of the antenna I when transmitting, referred to the electromotive force e_1 .

From the above relations we obtain, eliminating I_{01} , $e_1 = cr E_2 Z_{01} \sqrt{30 / D_1 R_{01}}$.

Similarly for the second antenna we can get $e_2 = cr E_1 Z_{02} \sqrt{30 / D_2 R_{02}}$.

Substituting the expressions for the electromotive forces in (1) and simplifying we get

$$(I_1 Z_{01} / E_1 \sqrt{D_1 R_{01}}) = (I_2 Z_{02} / E_2 \sqrt{D_2 R_{02}}).$$

⁶ We neglect, of course, the case when the rays pass through an ionized medium in presence of an external magnetic field, because in such a case the relation (2) and hence the principle of reciprocity are inapplicable.

⁷ P. S. Carter, C. W. Hansell, and N. E. Lindenblad, "Development of directive transmitting antennas for R.C.A. Communications, Inc.," *PROC. I.R.E.*, vol. 19, pp. 1773-1843; October, 1931.

Since all of the factors on the left side refer to antenna I and all the factors on the right refer to antenna II we can maintain, in view of the arbitrary antenna construction, that the expression $(I Z_{01} / E \sqrt{D R_{01}})$ in which all the factors refer to one antenna, gives a value which does not depend either upon the construction of that antenna or upon the properties of the surrounding medium. In order to determine this value we may consider any antenna. For simplicity's sake let us consider the ideal dipole of Hertz.

Thus let us assume that antenna II is a Hertz dipole situated in air. Let its length be dl and the angle which it forms with the direction of the arriving ray be θ . We then have $I_2 = (E_2 dl \sin \theta \cos \chi / R_{02})$, where χ is the angle between the planes of polarization of the rays received and sent out in the same direction.

Further, $D_2 = (3/2) \sin^2 \theta$; $Z_{02} = R_{02} = 20m^2 (dl)^2$, where $m = 2\pi/\lambda$. We therefore get $(I_2 Z_{02} / E_2 \sqrt{D_2 R_{02}}) = (\lambda/\pi \sqrt{120}) \cos \chi$. Considering the relation (2) we have $(I_1 Z_{01} / E_1 \sqrt{D_1 R_{01}}) = (\lambda/\pi \sqrt{120}) \cos \chi$. From this, discarding the subscript I we get for any antenna

$$I = (E \lambda \cos \chi / \pi) \left(\sqrt{\frac{DR_0}{120}} \right) \cdot 1/Z_0. \quad (3)$$

This important formula establishes a relation between the receiving current of the antenna at a certain point M and the field intensity of the arriving waves, it being noted that all the parameters entering into the formula (D_0, R_0, Z_0) are the parameters of the antenna when the latter transmits with the electromotive force applied at the same point M . Therefore this formula enables us to build up a theory of receiving antennas upon relations known in the theory of transmitting antennas.

Let us examine for purposes of illustration two particular cases. Let a half-wave unloaded radiator without losses serve as a receiving antenna. Let us place it perpendicularly to the direction of the incoming waves in the plane of the electric field vector ($\chi=0$). Let us find the current appearing at its mid-point. To do that let us examine a transmitting radiator of the same length excited at the middle. For the latter we have $Z_0 = R_0 = 73.2\Omega$; $D = (120/R_0) \{(\cos[\pi/2 \cos \theta])/\sin \theta\}^2$. Here θ is the angle between the axis of the radiator and the direction of the ray which it sends out. Since this direction must coincide with the direction of the arriving ray we must assume $\theta = \pi/2$. Thus in agreement with (3) we get $I = E\lambda/\pi \cdot 1/R_0$, which agrees with the results of direct computing.

For a 1-wavelength radiator we have, according to Ballantine, $E = (2I_{\max}/cr) \cdot (1 + \cos[\pi \cos \theta]/\sin \theta)$. Also when $\theta = \pi/2$, $D = 480/R_{\text{loop}}$. Further, $Z_0 = R_0 = W^2/R_{\text{loop}}$. Equation (3) gives $I = E\lambda/\pi \cdot 2/W$, which also agrees with the results of direct computing.

From (3) we get the following direct corollaries:

(1) The transmitting and receiving directivity characteristics of any antenna agree, if the received current is measured at the same point at which the electromotive

force is applied when the antenna is used for transmission.

(2) Any receiving antenna may be considered as a generator with an electromotive force, $e_a = (E\lambda \cos \chi / \pi) \sqrt{DR_0/120}$, and with an internal impedance Z_0 .

(3) The resonance curves and therefore the frequency bands for the rays which travel in a definite direction are the same for both the transmitting and receiving antennas if it is assumed that the angle of rotation of the polarization plane depends little upon frequency and if the resonance curves are described by the functions $I/E\lambda = f(\omega) \cdot \text{constant}$, for the receiving antenna and $E/e = f(\omega) \cdot \text{constant}$ for the transmitting antenna.

Both curves are described by the function of the form $f(\omega) = \sqrt{DR_0}/Z_0$.

Let us deduce a few more basic properties of the receiving antennas of any type using (3). In a general case of a loaded receiving antenna the impedance Z_0 consists of the following components:

$$Z_0 = R_a + R' + j(X_a + X').$$

Here: R_a = resistive component of the impedance equivalent to the antenna (in relation to the electromotive force)

R' = resistance of the useful load

X_a = reactive component of the impedance equivalent to the antenna

X' = reactance of the load

From the law of conservation of energy it follows that $R_a = R_0 + R''$, where R_0 is the radiation resistance of the antenna when transmitting, referred to the current at point M ; R'' is the resistance of antenna losses, also transmitting, and referred to the current at point M . Therefore, $Z_0 = R_0 + R'' + R' + j(X_a + X')$.

The power emitted in useful loading will be

$$P' = (1/2) I^2 R' = (E^2 \lambda^2 / \pi^2) (DR_0 / 240) \cdot (R' / Z_0^2) \cos^2 \chi.$$

Let us assume to begin with that there are no losses, i.e., $R'' = 0$. Then the maximum of useful power, as can be easily shown, will be obtained at $X_a + X' = 0$; $R' = R_0$.

Considering these conditions we obtain

$$P_{\max} = \frac{E^2 \lambda^2 \cos^2 \chi}{\pi^2} \frac{D}{960} \quad (4)$$

Thus the maximum power which the receiving antenna can abstract from the waves arriving from a given direction is determined exclusively by the coefficient of directive action of the antenna calculated for that direction with the antenna transmitting.

A still more lucid formula is obtained if the maximum area F_{\max} from which the antenna can absorb energy is calculated. Considering the fact that the power passing through the area F_{\max} , which is perpendicular to Poynting's vector S , is equal to $P_{\max} = F_{\max} \cdot S_{\text{eff}} = (c/8\pi) E^2 \cdot F_{\max}$ or, in practical units, $P_{\max} = (E^2/30) \cdot (F_{\max}/8\pi)$. Equating the powers and taking $\chi = 0$, we get

$$F_{\max} / \lambda^2 = D / 4\pi. \quad (5)$$

Thus a maximum area of wave absorption by the antenna, expressed in fractions of wavelength, is equal to the coefficient of the antenna directivity divided by 4π .

This latter result shows that, for instance, the maximum power which can be abstracted from the wave by loops and dipoles which are small in comparison with the wavelength, is absolutely independent of their dimensions, and is equal to $P_{\max} = (E^2 \lambda^2 / 960 \pi^2) \cdot (3/2) \sin^2 \theta = (E^2 \lambda^2 / 640 \pi^2) \sin^2 \theta$.

Here θ is the angle between the direction of the incoming waves and the axis of the dipole or the loop. When θ is equal to $\pi/2$ we get $P_{\max} = (E^2 \lambda^2 / 640 \pi^2)$; $(F_{\max} / \lambda^2) = (3/8\pi)$.

From (5) it follows that the use of antennas of sharp directivity is essential, when large power is to be abstracted from the waves.

The calculation of the power obtained by complex antennas (such as multidipole arrays, rhombic, V and W types, etc.) is not difficult inasmuch as the coefficients of their directivity are well known from the theory of transmitting antennas. It must be also noted that the results obtained give a lucid physical explanation of the fact that the coefficients of directivity of screen antennas are approximately directly proportional to the area of the screens.

Let us now assume the existence of losses in the antenna. Maximum of useful power emitted in loading will now take place at

$$X_a + X' = 0; \quad R' = R_0 + R'' \quad (6)$$

and will be equal to $P'_{\max} = (E^2 \lambda^2 / \pi^2) (D/960) \cdot (R_0 / (R_0 + R'')) = P_{\max} (R_0 / (R_0 + R''))$.

But the last factor is nothing but the efficiency η_A of the antenna when it transmits. Therefore, $P'_{\max} = P_{\max} \eta_A$.

This relation gives, for the case of the receiving antenna, an interpretation of the efficiency of a corresponding transmitting antenna. It is equal to the ratio of the maximum useful power which can be taken from the antenna to the greatest power which can be taken from an antenna having no losses.

Let us now consider for a general case, when the conditions of (6) are not met, the factor $\xi_A = P' / P'_{\max}$, i.e., the relation of useful power taken from the antenna to the greatest useful power which the antenna can give out when the load impedance is correctly chosen. We can call this factor a coefficient of exploitation of the receiving antenna.

We have

$$\xi_A = \frac{4(R_0 + R'')R'}{Z_0^2} = \frac{4(R_0 + R'')R'}{(R_0 + R'' + R')^2 + (X_a + X')^2}$$

$$P' = \frac{E^2 \lambda^2}{\pi^2} \frac{D}{960} \eta_A \xi_A \cos^2 \chi$$

The coefficient of exploitation obtains its maximum significance in the fulfillment of (6) when $\xi_A = 1$.

DISTINGUISHING CHARACTERISTICS OF RECEIVING AND TRANSMITTING ANTENNAS IN THE LIGHT OF RECIPROCITY THEOREM

The preceding discussion shows that the convertability of antennas from receiving into transmitting ones and vice versa follows from the reciprocity theorem. More than that, it follows that the better an antenna radiates energy the better it picks it up.

The relation of the power in a correctly selected useful loading of the receiving antenna II to the power supplied to the transmitting antenna I, i.e., the relation which determines the efficiency of radio transmission, can be represented by $(P_{\text{usef. rec.}}/P_{\text{inp. tr.}}) = D_1 \eta_{A1} D_2 \eta_{A2} \cdot A$. Here A is a constant, independent of antenna properties, and determined by the distance between them and by the condition of propagation of electromagnetic waves.

The properties of the transmitting antenna and the properties of the receiving antenna enter into the expression for the ratio of powers quite symmetrically, so that the interchange of the position of the antennas does not alter that ratio.

It follows that if the reciprocity principle would embrace fully the conditions taking place in radio communication, then the construction of the receiving and transmitting antennas should have been absolutely identical. In actual practice, however, we have to consider a series of conditions which are neglected by the reciprocity principle and which do justify the differences in the construction of receiving and transmitting antennas.

Let us determine these conditions. Let us consider the two most substantial groups of factors which we are facing in designing antennas, namely: (1) the nonunidirectivity of radio communications and (2) the nonlinearities which occur, or may occur in antenna work.

NONUNIDIRECTIVITY OF RADIO COMMUNICATIONS

Only one source and one receiver of electromagnetic waves appears in the formulation of the reciprocity principle. In actual practice, however, one must handle greater numbers of these. It is clear, therefore, that the considerations controlling the design of antennas as regards to their multiplicity, do not fit into the ramifications of the reciprocity principle.

We must note here, first of all, the case of broadcasting which involves the existence of a small number of transmitting antennas and of a great number of receiving antennas. It is obviously expedient in this case to construct relatively cheap receiving antennas and expensive transmitting ones (of high efficiency and with directive characteristics, at any rate, in the vertical plane).

An entirely different picture occurs in point-to-point radio communications when an equal number of receiving and transmitting antennas is used. Here the expenses for the improvement of both the receiving and transmitting antennas are equally justified. But even here we must cope with the nonunidirectivity of radio

communications which makes itself especially manifest in the existence of both natural and artificial sources of interference. Let us continue from this point of view. We have to consider two cases: (1) The case of strong interference (with long, medium, and fairly short waves) when the receiver's amplifying capacity cannot be fully employed and the required field intensity of the signal is determined by the interference level, and (2) the case of weak external interference (for very short and ultra-short waves) when the amplification is carried up to the limit determined by the fluctuating noises of the first tube.

1. The Case of Reduced Amplification.

The field intensity of the signals is given by the condition $P_{\text{sig}} \geq A \cdot P_{\text{interf}}$ where P_{sig} and P_{interf} are the power-input components in the useful loading of the antenna due to the signals and to the interference respectively while A is a constant.

We have $P_{\text{sig}} = (\lambda^2/960\pi^2) E_{\text{sig}}^2 D_2 \xi_2 \eta_2$, where D_2 , ξ_2 , and η_2 are the coefficients of directivity, of exploitation, and the efficiency of the receiving antenna.

Let us assume that the interferences reach the receiving antenna with equal probability from all directions with equal intensity and in random phase relations. Then, $P_{\text{interf}} = (\pi/4)(\lambda^2/960\pi^2) D_2 \text{mean} \xi_2 \eta_2 \sum E_{\text{interf}}^2$ where $D_2 \text{mean}$ is the mean coefficient of antenna directivity, $D_2 \text{mean} = (\int D \cdot d\omega / \int d\omega)$, $d\omega$ being an elementary spherical angle and the integration being performed over a sphere with the antenna in question at the center. The multiplier $\pi/4$ takes account of the mean probability of the power which is obtained from the addition of oscillations with random (equally probable) phases.

Let us evaluate $D_2 \text{mean}$, taking into consideration that $D = (cr^2 E^2 / I_0^2 R_0) = (cr^2 E^2 / 2P)$; $\int d\omega = 4\pi$, we get $D_2 \text{mean} = (cr^2 / 8\pi P) \int E^2 d\omega = (cr^2 / 8\pi P) \int (E^2 / r^2) df = (1/P) \int (c/8\pi) \cdot E^2 df$, where df is an element of the surface of the sphere with a radius r .

Since the latter integral is nothing but the power of radiation P we get $D_2 \text{mean} = 1$. Therefore,

$$P_{\text{interf}} = (\pi/4)(\lambda^2/960\pi^2) \eta_2 \xi_2 \sum E_{\text{interf}}^2.$$

Substituting the expressions for the power due to the signals and to the interferences into the fundamental inequality we get $E_{\text{sig}}^2 \geq (\pi/4)(A/D_2) \sum E_{\text{interf}}^2$.

Since the power of the transmitting radio stations P_{tr} is determined by the expression $P_{\text{tr}} = C \cdot E_{\text{sig}}^2 / \eta_1 D_1$ where η_1 and D_1 are the efficiency and coefficient of directivity of the transmitting antenna, and C is a constant, we get as a final result

$$P_{\text{tr}} \geq (\pi/4)(A/C) (\sum E_{\text{interf}}^2 / \eta_1 D_1 D_2).$$

In this manner we obtain the following results: (1) The highest possible directivity is of equal importance both in the transmitting and in the receiving antennas; (2) the efficiency of the transmitting antenna is of considerable importance, while the efficiency and the coefficient of exploitation of the receiving antenna have no significance.

There is no point, therefore, in trying to obtain a high

efficiency of the receiving antenna and to adjust precisely its load resistance. The practical usage in the construction of long-wave receiving antennas confirms these results (antennas poorly grounded, "aperiodic" antennas of low coefficient of exploitation, etc.).

Let us also note that with an uneven distribution of interferences in all directions the latter formula must be replaced by $P_{tr} \geq (\pi/4)(A/C)(D_{interf} \sum E_{interf}^2 / \eta_1 D_1 D_2)$, where D_{interf} is a mean coefficient of antenna directivity in relation to the unevenly distributed interferences. It is defined by $D_{interf} = (\sum [E_{interf}^2 \cdot D] / \sum E_{interf}^2)$.

If this coefficient is less than unity, which occurs during maximum interference from the sides and from the rear, then the application of a receiving antenna with the greatest possible directivity acquires double significance: the useful signal is intensified and simultaneously the interferences are weakened. In this case, therefore, it is rational to make the receiving antenna even more directional than the transmitting one. If D_{interf} is greater than unity, which occurs when the main interferences are coming from direction toward the transmitter, then the directivity of the receiving antenna is of less significance than the directivity of the transmitting one. In a limiting case, when all the interferences proceed in the same direction with the useful signals, the directivity of the receiving antenna loses all significance.

Avoiding a more detailed study of the question, let us note that when the distribution of interferences is undetermined beforehand the first case is more probable, and that this probability increases with the sharpness of antenna directivity and with the nonuniformity of interference distribution in different directions. It is to be believed, therefore, that there are even more grounds for securing a sharp directivity of the receiving antennas than that of the transmitting ones. Such a belief is supported by the fact that the directions of the interferences are sometimes, if only in a general way, known beforehand, and hence special steps can be taken to provide for "dead zones." All this refers to the directivities in the horizontal as well as in a vertical plane.

2. The Case of Maximum Amplification.

When the interference level is so insignificant that the useful sensitivity of the receivers is limited by interior noises, the condition for good reception will be $P_{sig} \geq P_{min}$, where P_{min} is a certain given power.

Considering the fact that $P_{sig} = (E^2 \lambda^2 / 960 \pi^2) D_2 \xi_2 \eta_2$ and on the other hand $E^2 = (P_{tr} D_1 \eta_1 / C)$, we get $P_{tr} \geq (C \cdot 960 \pi^2 / \lambda^2) (P_{min} / D_1 \eta_1 D_2 \xi_2 \eta_2)$.

When the load resistance of the receiving antenna is correctly adjusted, $P_{tr} \geq (C \cdot 960 \pi^2 / \lambda^2) (P_{min} / D_1 \eta_1 D_2 \xi_2 \eta_2)$.

Thus, in this case, we obtain the following results:

(1) The directivities of both the receiving and transmitting antennas are of equal importance.

(2) The efficiency and coefficient of exploitation of the receiving antenna are just as important as the efficiency of the transmitting antenna.

In the foregoing discussion we neglected the plane of polarization of the waves which reach the receiving antenna. Where it is permissible to think that the plane of polarization of the greater part of interferences is more or less constant in time and is different from the plane of polarization of the signals, we should then have an additional way of selection from interferences.

NONLINEARITIES

Let us now consider the second group of conditions which determine the differences in the construction of receiving and transmitting antennas. These are the nonlinearities which do, or may take place in the performance of antennas.

Before all else this group includes phenomena of nonlinear characters which occur at high antenna voltages, such as the breakdown of insulators and discharges into the air (corona in long waves, and standing arcs or torches in short waves). Considerations concerning the prevention of these phenomena, while playing an important part in powerful transmitting-antenna design, are of no significance in the case of receiving antennas. Thus the difference in the insulation of receiving and transmitting antennas is justified. Furthermore, in the case of the receiving antennas there is no need of increasing the capacitance and radiation resistance for lowering of voltage. In the case of reduced amplification the radiation resistance has its principal significance in the efficiency and the conditions of adjustment of load resistance. In the cases of maximum amplification even these considerations vanish.⁸

It is natural, therefore, to use in the case of long waves, antennas of one wire. On the other hand for purposes of short-wave reception, systems of low radiation resistance (such as directors, passive reflectors, etc.) may be more widely used.

Also let us note that the multiple use of antennas for purposes of reception is simpler than for purposes of transmission since in the former case the increase of antenna voltage does not have to be considered.

The second group of nonlinearities is manifest in those cases where the work of antennas depends upon vacuum tubes. As a typical instance of these, we may mention the well-known method of spaced antennas, employed in short-wave schemes, designed to counteract fading (diversity system). Inasmuch as this method gives good results only when the signals arriving from different antennas are combined after detection, it is dependent upon the nonlinear characteristics of the tubes and, therefore, cannot be adopted to transmitting antennas.

The arrangement of the coupling circuits between the tubes and antennas (tank circuits of the output stages of transmitters and the input circuits of receivers) will be different too since these are impedance transformers with the magnitude of the required impedance

⁸ It must be noted, however, that the criteria for passing the entire frequency band through antennas apply also to the receiving antenna.

transformation being determined by the characteristics of the tubes. Further differences are determined by nonlinear phenomena due to overheating and to breakdown of insulation in couplings.

In feeding through transmission lines with a traveling wave, two transformers are required, one between the antenna and the line and the other between the line and the tubes. The first transformer (if nonlinear phenomena connected with high power are neglected) must be the same for both transmission and reception because, in the first case, consideration of feeder losses requires matching the equivalent antenna resistance and the characteristic impedance of the line, while in

the latter case it is necessary to match the loading and equivalent antenna resistance.

CONCLUSIONS

In summarizing we may say that:

(1) The principle of reciprocity enables us to obtain all of the characteristics of receiving antennas from the known characteristics of the transmitting ones, avoiding involved direct computing, and in a very simple manner.

(2) The principle of reciprocity gives a convenient criterion for evaluating and explaining the peculiarities of receiving-antenna construction as compared with that of transmitting antennas, and vice versa.

Antenna Arrays Around Cylinders*

P. S. CARTER,† MEMBER, I.R.E.

Summary—Arrays of dipoles around spires or other vertical supports are useful for the broadcasting of ultra-high-frequency waves. To the author's knowledge no sound method of computing the radiation patterns which takes into account the effect of the support has previously been presented. The three arrangements of dipoles around a vertical cylinder which are of interest are (1) an array of vertical dipoles, (2) an array of horizontal dipoles whose axes lie on the circumference of a circle, and (3) an array of horizontal dipoles whose axes point radially outward. There are several phase relationships for the currents which are of practical interest for each of these arrays.

The necessary number of dipoles in various types of arrays to obtain a horizontal radiation pattern approaching a circle within any specified tolerance are shown by curves. The interference phenomena caused by a plane wave passing a vertical cylinder are discussed and shown graphically. Several radiation patterns for one dipole near a cylinder are discussed. A detailed study of a 4-element horizontal dipole array surrounding a cylinder whose diameter is 1.27 wavelengths, or whose periphery approximates that of the Chrysler Building spire at the assigned television frequency, has been made. Both horizontal and vertical patterns for three different phase relationships of the dipole currents have been calculated.

Formulas for the radiation patterns for arrays of all three types having various numbers of elements and fed in several different ways are tabulated.

The method of obtaining a rigorous solution of Maxwell's equations for a dipole near a long cylinder is outlined. By making use of the reciprocity theorem infinite integrals in the terms of the Fourier-Bessel series are avoided. When the expression for the field from one dipole and cylinder has been obtained it is a simple matter to develop the expression for an array of any number of elements.

When the diameter of the support is large in terms of wavelength arrays of two or more tiers are necessary to avoid waste of energy in high-angle radiation. A substantially circular horizontal pattern can always be obtained.

INTRODUCTION

FOR television and sound broadcasting with ultra-short waves it is often desirable to use arrays of radiators surrounding vertical projections from tall buildings such as the Empire State Building mooring mast and the Chrysler Building spire. Usually such

structures are good conductors at high frequencies, being constructed with stainless steel or other metallic surfaces. One would naturally expect the currents which flow in such conducting structures to have a substantial effect upon the radiation patterns of antenna systems which they support. This paper shows how such characteristics may be calculated and discusses in detail some arrangements of importance in practice. If we assume a supporting structure to be a long perfectly conducting cylinder a rigorous mathematical solution for the radiation fields is possible. In practice where the vertical structures may not be of cylindrical form the radiation patterns should differ little from those computed for a cylindrical form if the periphery of the theoretical cylinder is made equal to the periphery of the actual structure. For broadcast purposes we are usually interested in obtaining a substantially circular radiation pattern in the horizontal plane and as little waste of energy as possible at high angles above the horizon.

Unfortunately, the mathematical theory necessary to develop the expressions giving the radiation characteristics is not readily understandable by one unfamiliar with the vector calculus, the partial differential equations of wave motion, and the properties of Bessel functions. An attempt will be made to give a nonmathematical explanation of the physical principles involved but first we shall discuss the characteristics of some arrangements of practical importance.

GENERAL CONSIDERATIONS—CIRCULAR ARRAYS

In the design of a circular antenna array we usually wish to use the minimum number of units which will produce a satisfactory horizontal radiation pattern. The term "circular array" as used here is intended to include all arrays consisting of any number of units evenly spaced at equal distances from a fixed point. The array may consist of two units at diametrically opposite points, three units at the corner of an equilateral

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† Radio Corporation of America, RCA Laboratories, Rocky Point, Long Island, New York.

triangle, four units at the corners of a square, etc.

Usually, but not always, the number of units required to obtain a substantially circular pattern in the hori-

zontal plane is at least as great when the array surrounds a conducting cylinder as when the same array is free from the cylinder. It is, therefore, well to give some

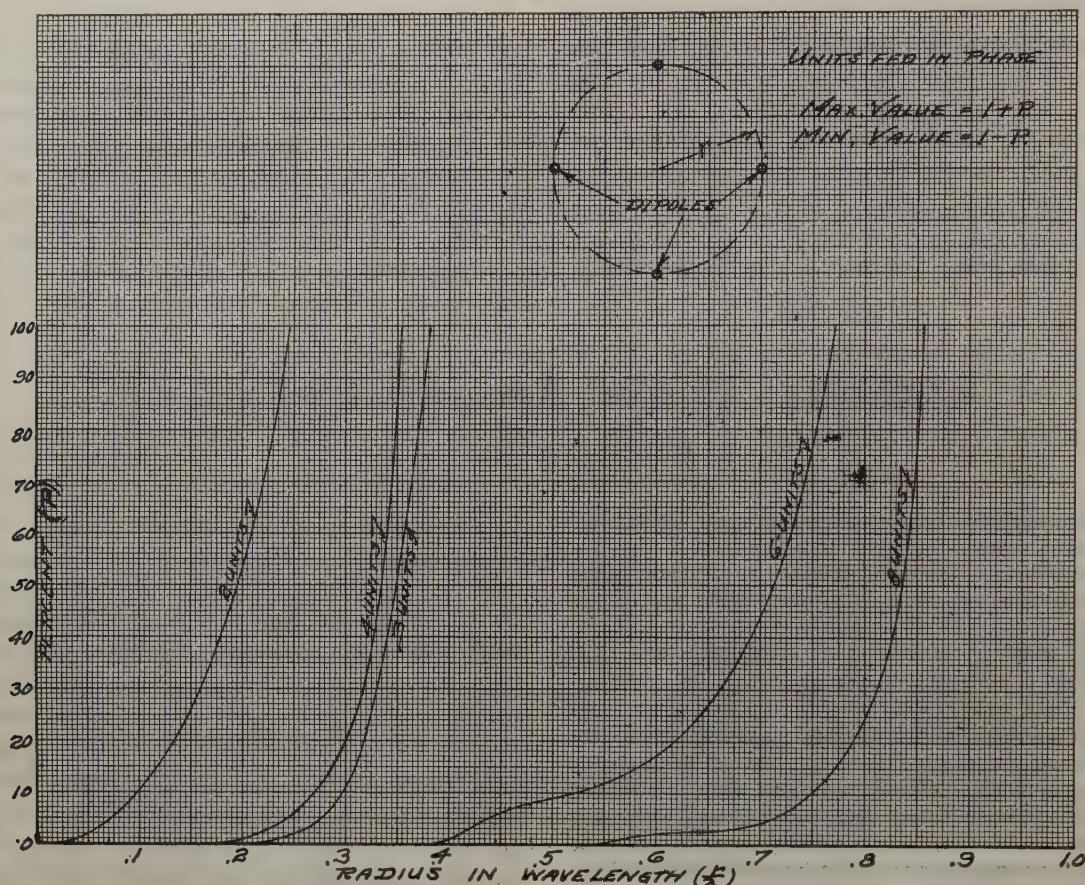


Fig. 1—Vertical dipole arrays. Variation in field strength with horizontal angle. (In phase.)

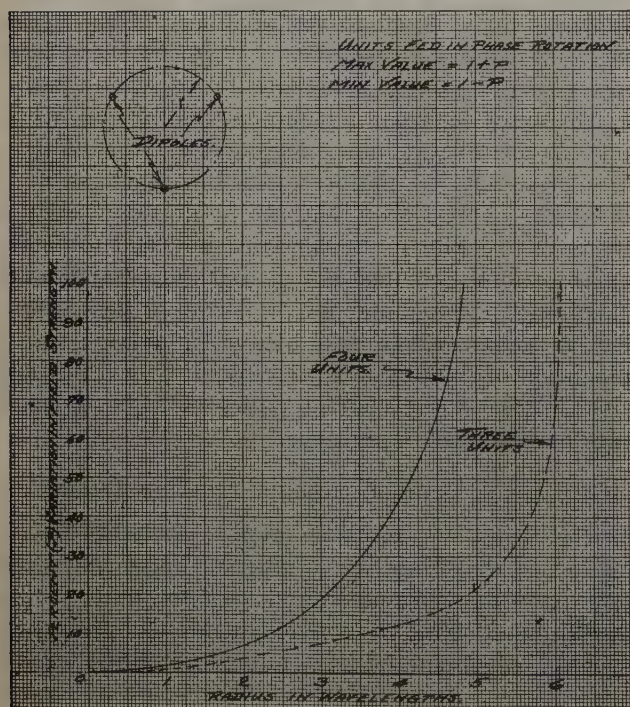


Fig. 2—Vertical dipole arrays. Variation in field strength with horizontal angle. (Phase rotation.)

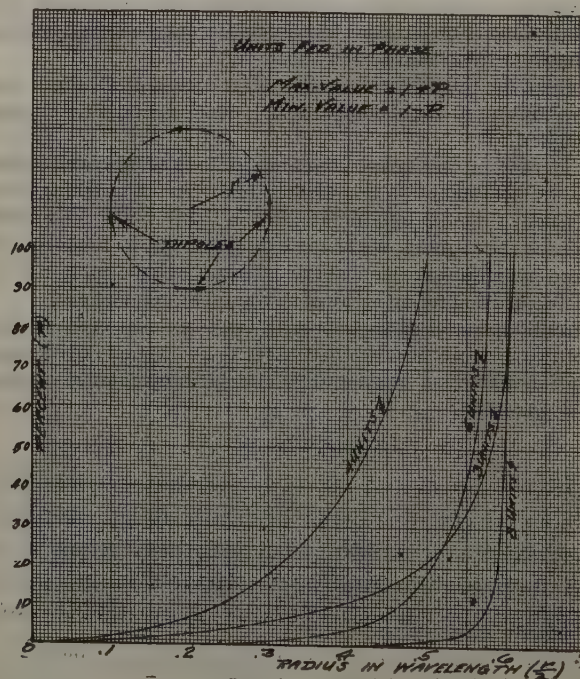


Fig. 3—Horizontal dipole arrays. Variation in field strength with horizontal angle.

consideration to circular arrays by themselves before proceeding to a study of the effects of a cylinder.

Consider first arrays of vertical dipoles fed in phase. A perfect circular pattern will, of course, be obtained by the use of a single unit. If two units are used the spacing must be quite small to prevent a large variation in field with direction. As the diameter of the circle is increased the number of units must be increased to prevent a large variation in radiation with direction. The curves of Fig. 1 have been plotted to show the effects of diameter and number of units on the horizontal pattern.

field with the radius for 3- and 4-unit arrays of this type.

For horizontally polarized radiation we may wish to use an array of horizontal dipoles, where the axes of these dipoles lie on the circumference of a circle. We assume these units to be fed in phase, i.e., that the instantaneous directions of the currents are all in the same sense around the circumference. Fig. 3 shows the manner in which the pattern varies with the radius and the number of units. It will be noticed that the 3-unit array is very much superior to the 4.

Another arrangement of interest for the radiation of

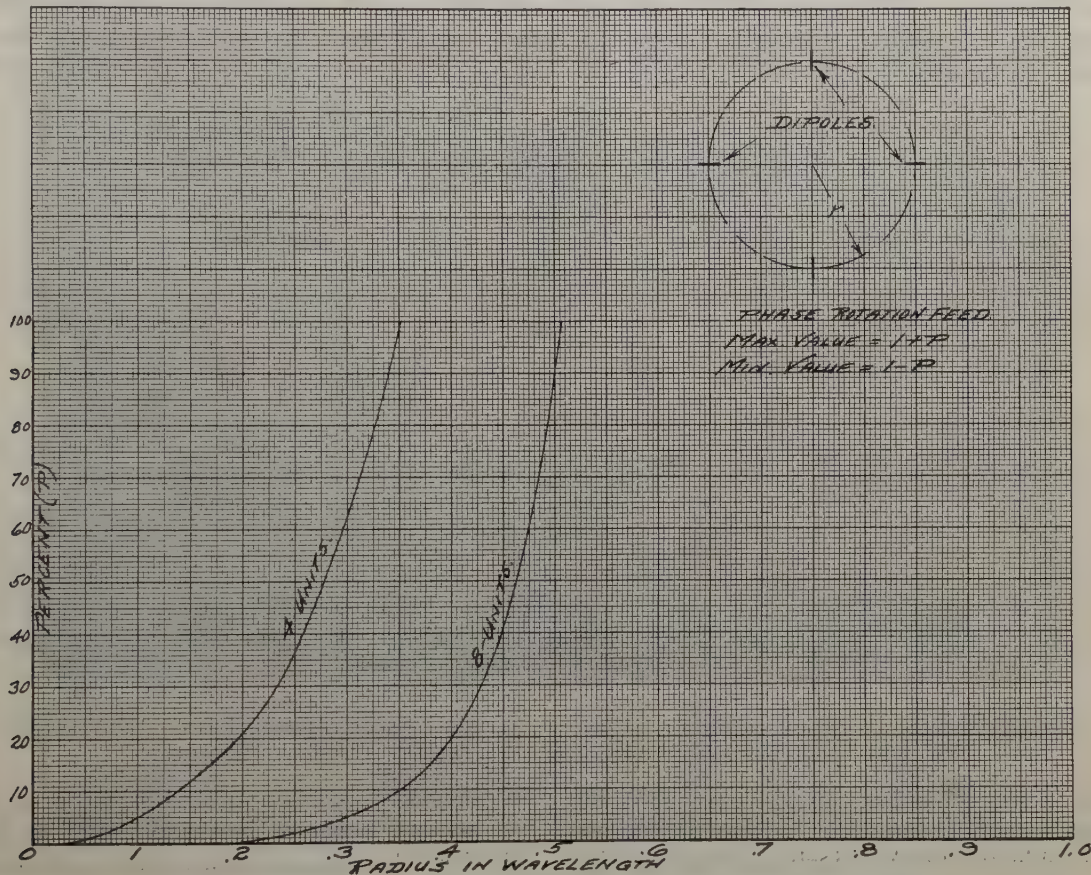


Fig. 4—Radial dipole arrays. Variation in field strength with horizontal angle.

The per cent variation in field strength with direction is plotted as a function of the radius of the circle in wavelengths for arrays of 2, 3, 4, 6, and 8 units. For any particular tolerance we may immediately find the minimum number of units which can be used for a given radius. For example, if we specify the variation as less than 10 per cent we find that at least 3 units must be used for a radius of one-quarter wavelength. For a half-wavelength radius 6 units are necessary. It is of interest to note that a 3-unit array is superior to one of 4 units.

Other arrays of vertical dipoles of interest are those of 3, 4, and 6 units fed in phase rotation, that is, in which the current in each dipole leads that in the preceding dipole by $360 \text{ degrees}/n$ where n is the total number, and each unit is considered in order following around the array. Fig. 2 shows the per cent variation in

horizontally polarized waves is an array of horizontal dipoles in which the dipole axes are directed radially. The pairs of units are fed in a phase relation corresponding to their position on the circle. In a 4-unit array the pairs are in quarter phase relation while in an 8-unit array adjacent pairs have a 45-degree phase relationship. Curves similar to the preceding are shown in Fig. 4 for this array.

So far we have failed to mention the effect of the radius and number of dipoles in circular arrays upon the radiation patterns in vertical planes. Although we may obtain a nearly circular horizontal pattern from arrays of considerable radius by using a sufficient number of units, the radiation at high angles to the horizon increases greatly with increase in diameter. To avoid this waste of energy it becomes necessary to use two or more tiers.

DIFFRACTION BY A TALL CYLINDER

Before proceeding with a discussion of the effects of a cylinder upon near-by dipole antennas it may be well to try to get a picture of the phenomena of diffraction by a tall cylinder. Let us assume that we have a vertically polarized electromagnetic wave coming from a distant source and that in its path is placed a long vertical cylinder. The electric field of this wave sets up currents in the surface of the cylinder which are responsible for a secondary electromagnetic wave diverging outwardly from the cylinder. In the case of reflection from a plane surface we ordinarily picture a main and reflected wave, the reflected wave traveling in the opposite direction to the direct wave for the condition of

This result would be expected from physical reasoning since both primary and secondary waves are traveling in the same direction and no rapid change of phase between these two components can take place. The total field intensity for directions at right angles to the direction of the primary wave is shown in Fig. 6. Here we have an interference phenomena similar to that for the direction directly in front of the cylinder but differing in that the distance between maxima and minima is now approximately a half wavelength rather than a quarter wavelength as in the preceding case. This is in accordance with physical intuition since in this direction the phase between the primary and secondary fields depends only upon the phase of the secondary field so that

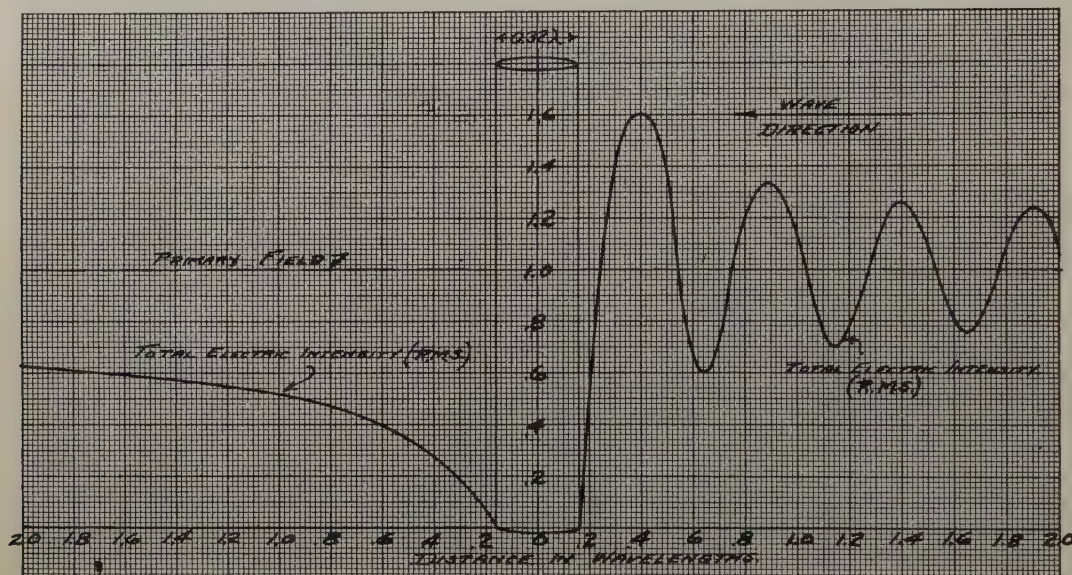


Fig. 5—Diffraction of vertical polarized wave by long vertical cylinder. (Front and back.) Total electric field directly in front of and behind cylinder. See Fig. 6 for intensity at right angles.

perpendicular incidence. In the case of the cylinder the effect is somewhat similar but differs in that the secondary waves travel in all directions including the direction directly in back of the obstruction. The curves in Fig. 5 show a picture of the phenomenon for a cylinder having a diameter of 0.32 wavelength. To the side of the cylinder directly toward the source the combination of primary and secondary fields results in a standing wave in a manner quite similar to that for reflection from a plane conductor. At all points on the surface of the conductor the electric-field intensity must of course be zero. At distances greater than about a wavelength from the cylinder the maxima and minima of the standing wave are $\frac{1}{4}$ wavelength apart as would be expected but in the region close to the cylinder the law governing the total field is rather complex due to the fact that the secondary wave is a diverging, cylindrical wave. In the direction directly behind the conducting obstruction the intensity of the electric field builds up in a smooth curve and gradually approaches the strength of the primary field as the distance increases. There is no standing-wave phenomenon in this direction.

positions of opposition and addition occur only half as fast as they occurred in the direction in front of the cylinder. This phenomenon is quite similar to the condition when surface waves on the water encounter an obstruction such as a lighthouse on a circular foundation or a government "can" buoy. A close scrutiny of the wave phenomenon near a can buoy in a light breeze when the waves are short will be found very enlightening. The diameter of these buoys is too small compared to a wavelength of water waves, present under other than light breezes, to produce the interference phenomena of interest here.

The current distribution on the surface of the cylinder is shown in Fig. 7. The broken curve shows the phase angle with reference to the phase of the electric force of the primary field at the axis of the cylinder.

VERTICAL DIPOLE AND CYLINDER

In order to show the effect of a conducting cylinder upon the horizontal radiation pattern of a vertical dipole for one range of conditions, a fixed distance of 0.24 wavelength from the axis of the cylinder to the dipole

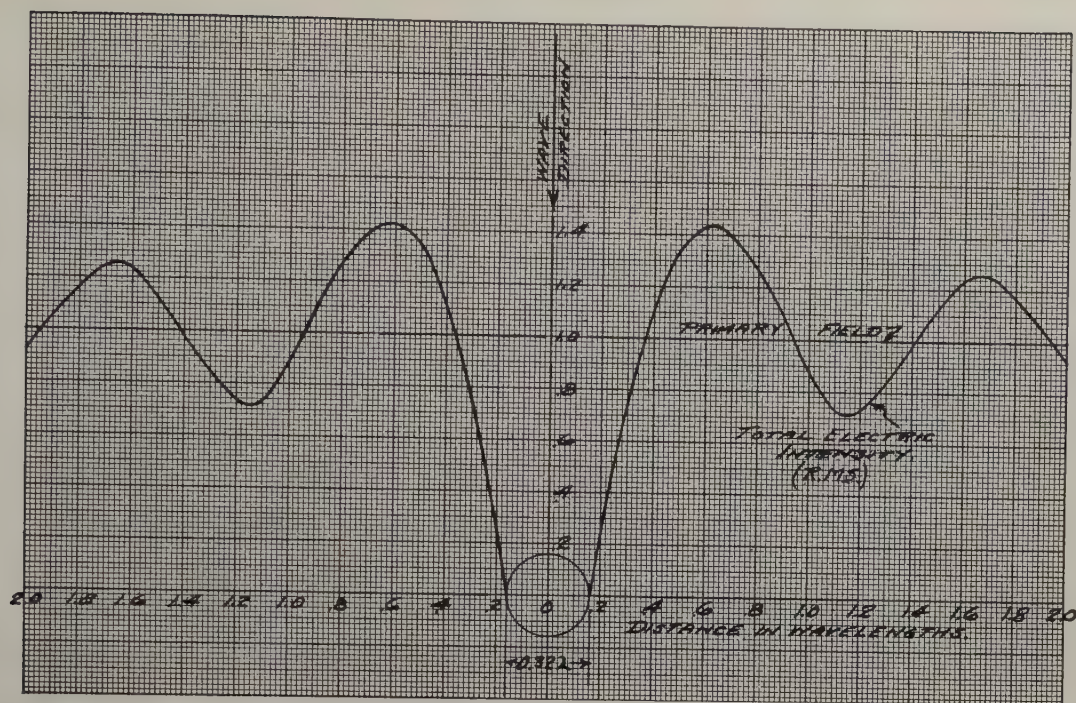


Fig. 6—Diffraction of vertical polarized wave by long vertical cylinder. (At side.) Total electric field in direction at right angles to primary wave direction. See Fig. 5 for intensity in other directions.

has been assumed and the radius of the cylinder allowed to increase from a very small value until the cylinder becomes of such a size as to be almost in contact with the radiator. Fig. 8 shows the pattern when the radius of the cylinder is 0.0016 wavelength, which is equivalent to about 0.4 inch at a frequency of 50 megacycles. It will be noted that the radiation diagram does not differ greatly from a circle. In Fig. 9 the radius of the cylinder has been increased to about 0.03 wavelength. It is seen

that the distortion from a circular pattern has considerably increased over that shown in the first-mentioned drawing. However, there is no definite relationship between the geometrical shadow as indicated and the shape of the pattern. In Fig. 10 the radius of the cylinder is 0.08 wavelength. Although there is no indication in the pattern of a demarcation between lighted and shadow regions the radiation is very much less at the middle of the shadow region than in the opposite

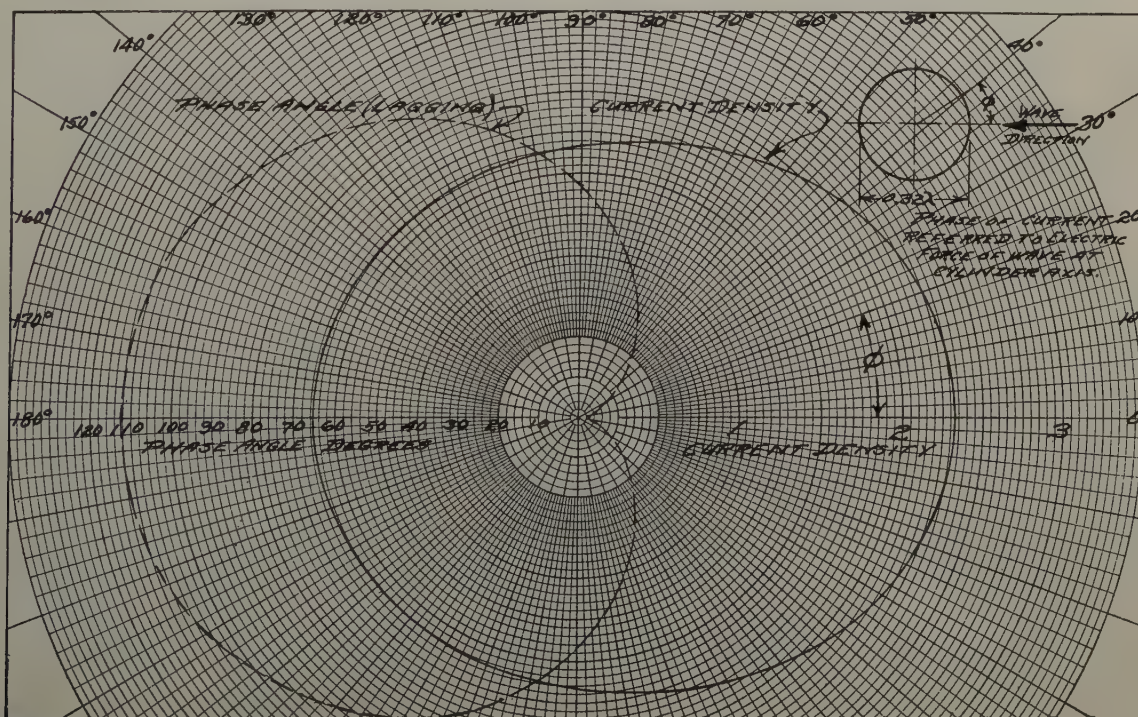


Fig. 7—Current distribution on cylinder for plane wave vertically polarized.

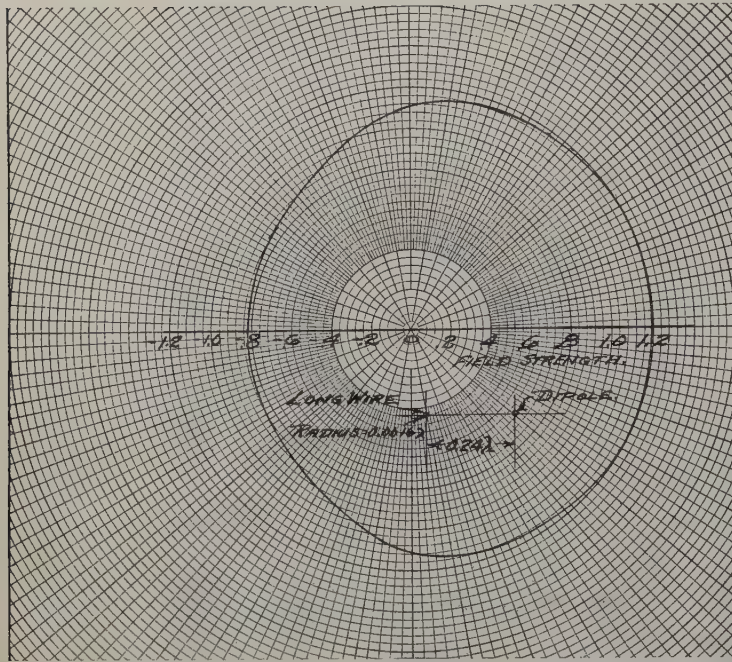


Fig. 8—Vertical dipole and long wire.

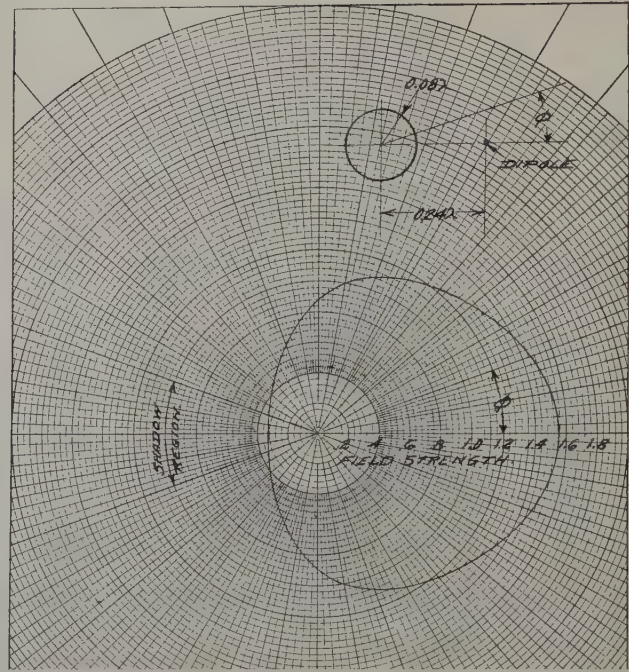


Fig. 10—Vertical dipole and cylinder. (B)

direction. In Fig. 11 the radiation pattern is shown for a cylinder radius of 0.16 wavelength. This pattern is quite unidirectional and the depression in the diagram tends to approximate coincidence with the shadow area. In Fig. 12 the cylinder radius is increased to nearly 0.24 wavelength so that it nearly touches the dipole. The shadow area for this condition covers an angle of 180 degrees and the radiation pattern tends to follow the outline of the shadow area.

It should be emphasized that the general character-

istics brought out by the preceding radiation patterns are not necessarily typical. For larger cylinders there are pseudo resonance effects so that under some conditions more radiation may take place in the direction corresponding to the center of the geometric shadow area than in the opposite direction. Also it should not be assumed that the pattern for an array of dipoles can be obtained by direct addition of the diagrams shown. These diagrams only show the absolute magnitude of the field intensity as a function of direction and give no

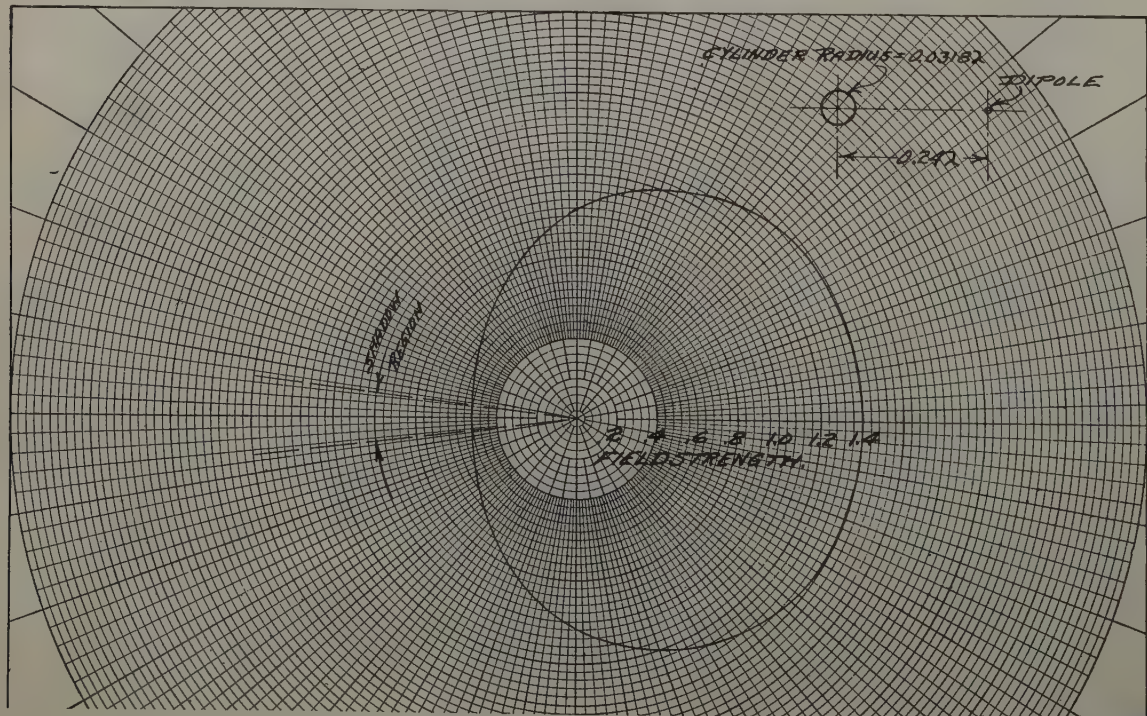


Fig. 9—Vertical dipole and cylinder. (A)

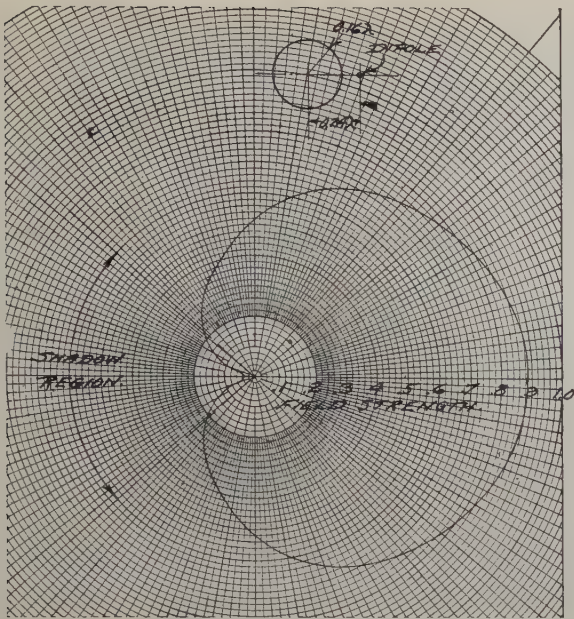


Fig. 11—Vertical dipole and cylinder. (C)

indication of the variation in the phase of the waves with rotation about the center of the cylinder. The phase relations vary in a rather complex manner with direction.

Fig. 13 shows a pattern for a vertical dipole and a cylinder when the radius of the cylinder is 0.383 wavelength and the distance of the dipole from the cylinder axis is 0.878 wavelength. It will be noted that this pattern is quite different from those patterns for a smaller cylinder which we just considered. The radius of this cylinder was purposely chosen of a value such as to result in a zero constant term in the Fourier series expression for the field as a function of direction angle.

ARRAYS OF VERTICAL DIPOLES
AROUND A CYLINDER

If to the arrangement of Fig. 13 we add a second dipole in a diametrically opposite position to the original

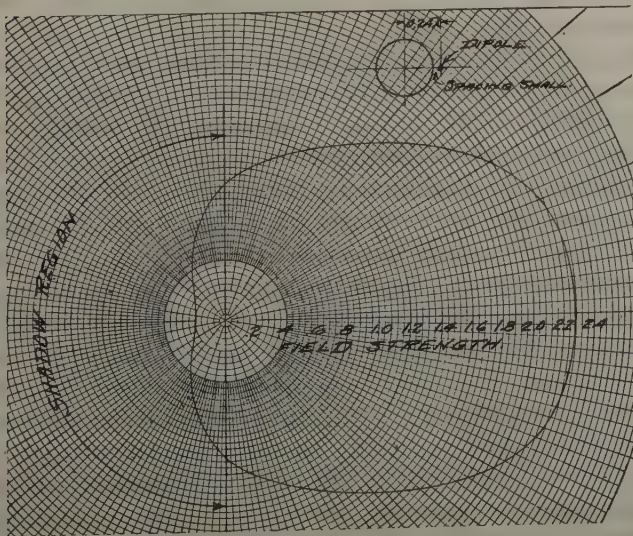


Fig. 12—Vertical dipole and cylinder. (D)

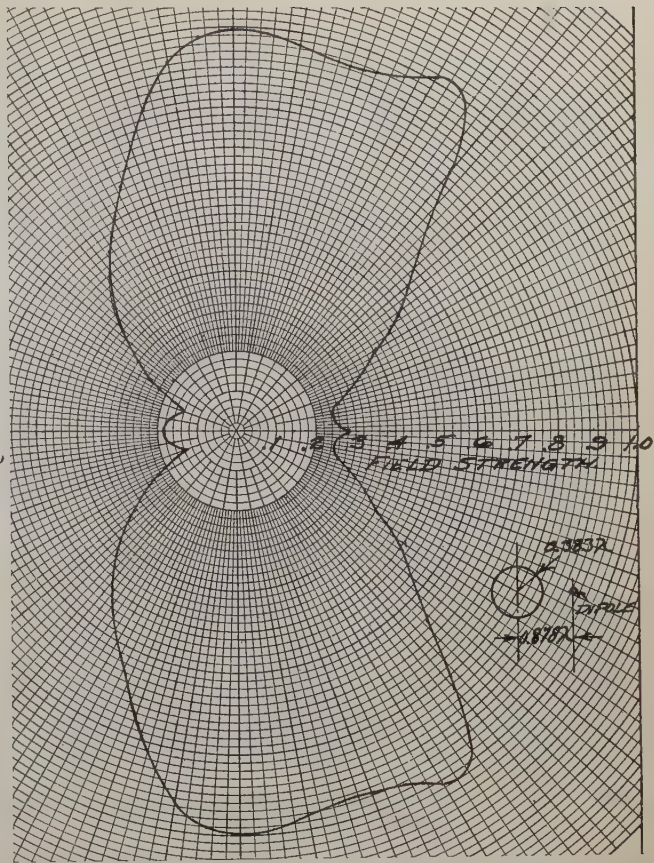


Fig. 13—Vertical dipole and cylinder. Horizontal Pattern.

dipole and feed the two units in phase with each other we obtain the horizontal radiation pattern of Fig. 14. The addition of two more radiators so as to form a square external to the cylinder results in the pattern of

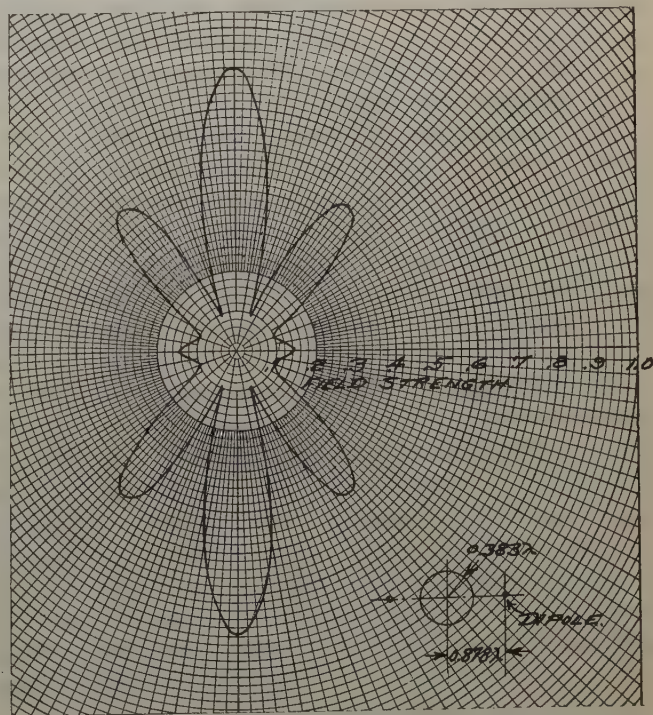


Fig. 14—Two vertical dipoles and cylinder. Dipoles fed in phase. Horizontal pattern.

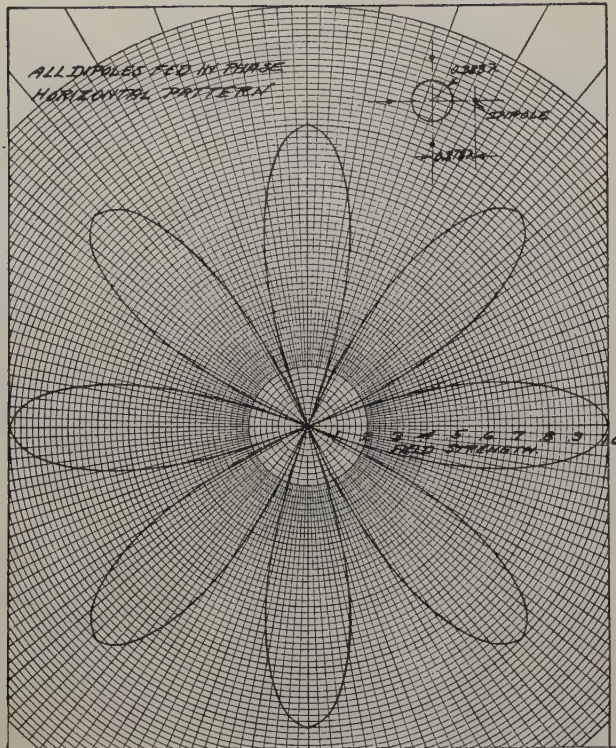


Fig. 15—Four vertical dipoles and cylinder. All dipoles fed in phase. Horizontal pattern.

Fig. 15. There are four ears and four zeros in this pattern and it is almost the same as the radiation characteristic for the same four dipoles without the conducting cylinder.

Fig. 15 is a good illustration of the fact that usually, although not always, if, from the broadcast viewpoint, the pattern for a particular array of dipoles alone is poor it will still be poor when the same array surrounds a cylinder. As a general rule, when designing an antenna array to surround a structure, the units being at a particular distance from the axis of the structure, a sufficient number of units should first be chosen to result in a substantially circular pattern for the array by itself. The best radius for a circular array of vertical dipoles is zero. In other words a single dipole without any support is the best unit that can be used for broadcasting. If we have a choice of the diameter of the support and can make it a small fraction of a wavelength a very good pattern can be obtained from an array of three or more dipoles surrounding the support. In practice the support often already exists as a spire on a building so that we have no choice of either the diameter of the equivalent cylinder nor the frequency and must make the best of the existing conditions. It is always possible to obtain a substantially circular pattern from an array around a cylinder regardless of its diameter if a sufficient number of units is used but large diameters result in very large radiation at high angles unless two or more arrays are arranged in tiers.

When the diameter of the support is not great a useful arrangement for broadcasting vertically polarized waves

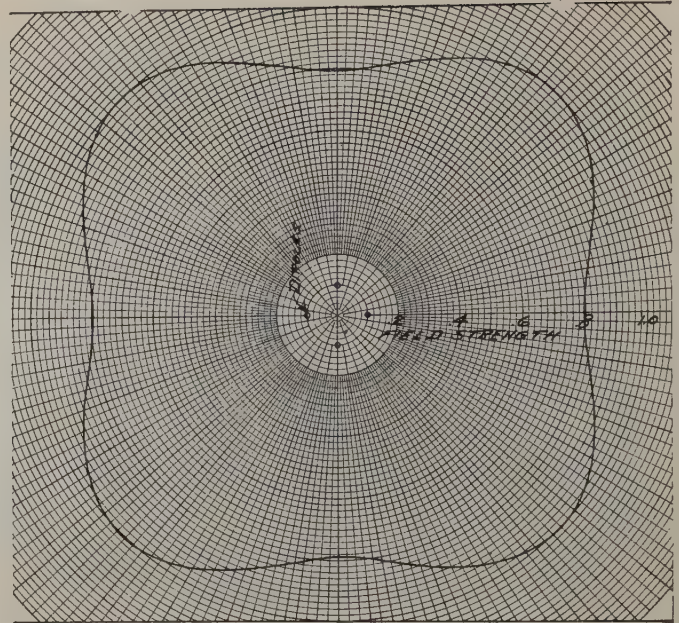


Fig. 16—Field-strength pattern. Four vertical dipoles. Phase rotation.

is an array of 4 dipoles fed in phase rotation. The current induced in the cylinder is negligible when its radius is a small fraction of a wavelength with such an arrangement and if the dipole centers are at a radius of less than $\frac{1}{4}$ wavelength the pattern is circular within ± 10 per cent. Fig. 16 shows the pattern when the dipoles are at a radius of one-quarter wavelength.

Experience shows that in most locations the signal-to-noise ratio is better when horizontal polarization is used in transmission than when vertical polarization is used. For this reason we shall confine our attention primarily to antennas radiating horizontally polarized waves.

HORIZONTAL DIPOLE AND VERTICAL CYLINDER

When a horizontal dipole is placed near a conducting cylinder currents flow around the cylinder and their effect upon the radiation field is quite different than when they flow up and down as in the case of a vertical dipole. Fig. 17 shows the horizontal pattern for a horizontal dipole placed 0.24 wavelength from the axis of a vertical cylinder having a radius of 0.16 wavelength. This pattern shows two phenomena of importance. The radiation is approximately the same in the direction corresponding to the center of the geometrical shadow as it is in the reverse direction. This fact shows how far astray conclusions based upon geometrical optics may lead us. The radiation of a horizontal dipole by itself in the direction corresponding to a continuation of its axis is zero but, when a vertical cylinder is placed near the dipole, the radiation in this direction may be substantial. It is far from zero for the arrangement of Fig. 17.

While a study of the effects of cylinders of various sizes upon the radiation pattern for a horizontal dipole placed at various distances might be interesting much labor is involved in making the necessary computations.

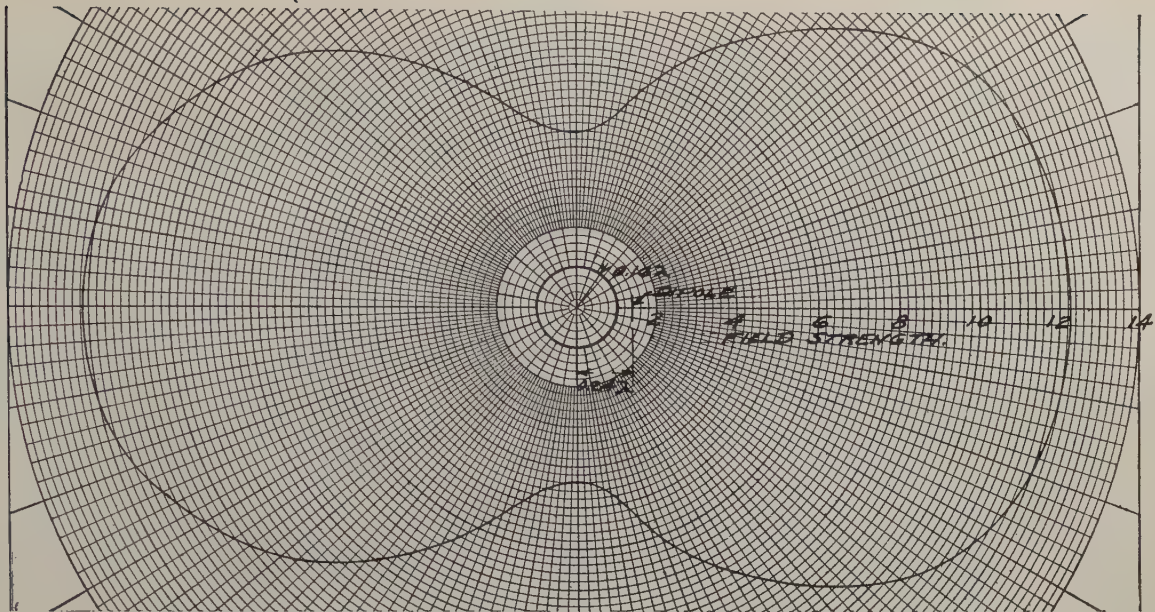


Fig. 17—Horizontal dipole and vertical cylinder. Horizontal pattern.

Since our primary interest here is in the characteristics of the arrays we shall pass on.

HORIZONTAL DIPOLES AROUND CYLINDERS— DIPOLE AXIS CIRCUMFERENTIAL

A detailed study of arrays of four elements surrounding a cylinder having a radius of 0.637 wavelength or a periphery of 4 wavelengths has been made. It is understood that the spire of the Chrysler Building has approximately this periphery at the frequency of the television transmitter located there. The openings in the spire of this building limited the number of radiators which could be used to four. There are three methods of feeding such an array which are of interest:

1. All the elements may be fed in phase.
2. Diametrically opposite elements may be fed in phase while the pairs of such elements are fed in quarter-phase relation.
3. Diametrically opposite units of a pair may be fed in phase opposition while the pairs are fed in quarter-phase relation.

Before proceeding it is important to have clearly in mind proper definitions of "in phase" and "in phase opposition." For our purposes here we shall define "in phase" as that condition when the instantaneous currents in the various dipoles of the circular array have the same direction when viewed looking toward the axis of the cylinder from a position outside of the cylinder. In other words, if the currents in the four units are in phase and their instantaneous directions are represented by arrows all arrows will point in the same direction if we walk around the cylinder and view them facing the cylinder. This viewpoint is opposite to that ordinarily taken when considering one pair of horizontal dipoles but any other definition in connection with a circular array would cause confusion. In accordance

with this definition the third method of feeding mentioned above is equivalent to a phase-rotation feed.

(a) In-Phase Feed

Fig. 18 shows the horizontal pattern when the above-stated arrangement of four dipoles and cylinder are fed in phase. The field distribution is far from circular. The dashed curve in the drawing shows the horizontal radiation pattern for the same array without the cylinder. It will be noted that the maxima of one pattern correspond to the minima of the other.

The horizontal pattern is only one part of the story. We also need to know the distribution in vertical planes.

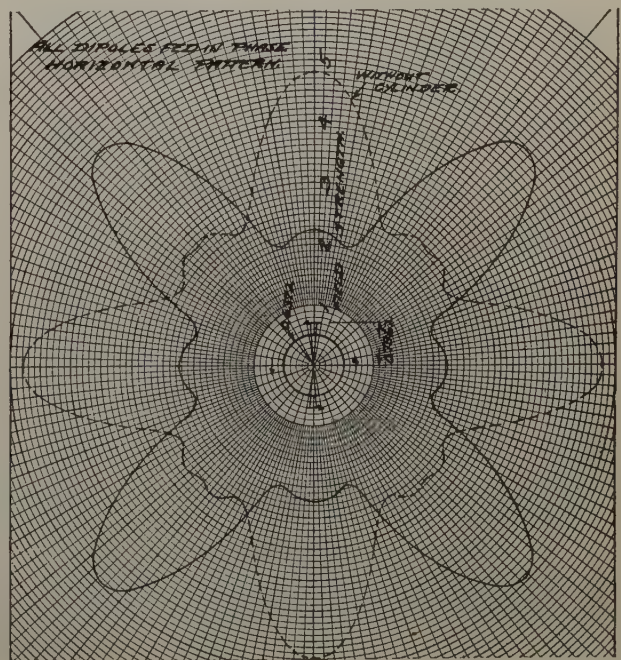


Fig. 18—Four horizontal dipoles and cylinder. (1).

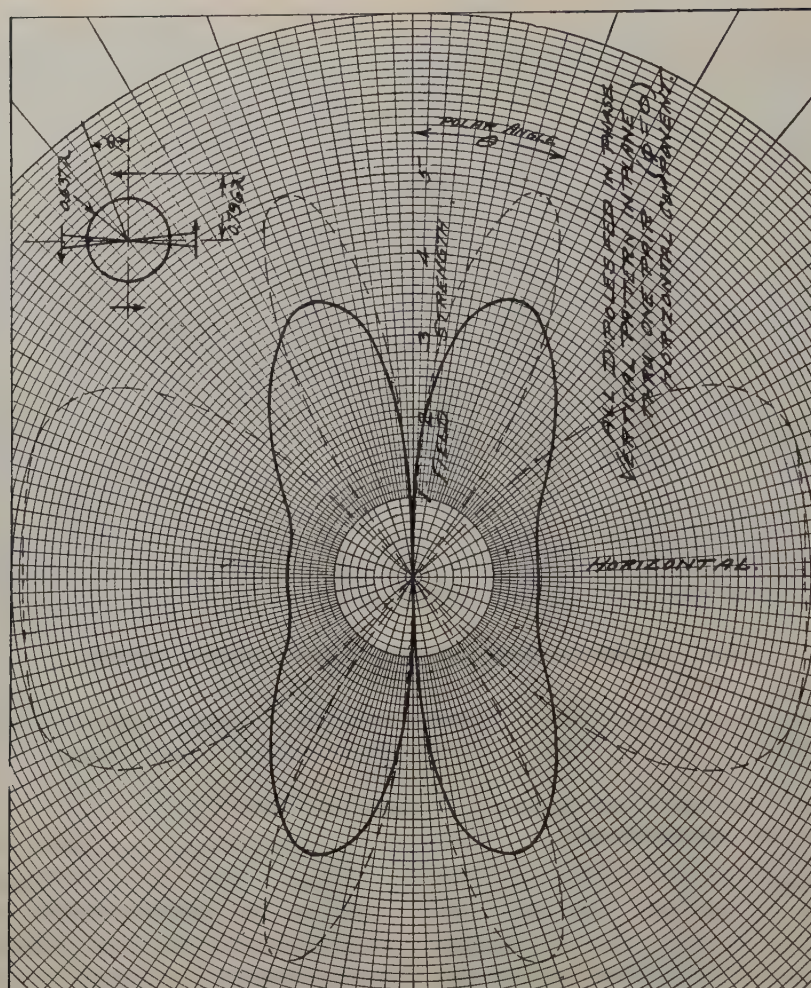


Fig. 19—Four horizontal dipoles and cylinder. (A).

Fig. 19 shows the pattern in a vertical plane containing the centers of two diametrically opposite dipoles. At an angle of 20 degrees to the vertical the field strength is over twice that in the horizontal directions. Thus the energy radiated at this high angle is about five times that radiated horizontally. Fig. 20 shows the radiation characteristic in a vertical plane which passes halfway between the pairs of diametrically opposite dipoles. In this plane the energy radiated at an angle of about 35 degrees to the vertical is approximately $2\frac{1}{2}$ times that radiated horizontally. Fig. 21 shows the radiation pattern in a vertical plane making an angle of 22.5 degrees to the plane passing through a pair of diametrically opposite units. For waste of energy at high angles this is the worst of the three vertical planes, the energy radiated at an angle of 25 degrees to the vertical being more than 7 times that radiated horizontally. If a second tier of units is placed at a height of 0.575 wavelength above the first set no radiation can take place at an angle of 30 degrees to the vertical and the patterns in vertical planes will all become fairly satisfactory. However, the horizontal pattern is, of course, unchanged and is far from ideal for broadcasting.

(b) *Two Dipoles of Pair in Phase—Pairs in 90-degree Phase Relation*

Fig. 22 shows the horizontal pattern for four dipoles around a cylinder when the feeding system is connected so as to result in this condition. This pattern brings out the result of a peculiar phenomenon which needs explanation. First it should be emphasized that this is *not* the condition of phase rotation feed. At first sight it might seem that the pattern should repeat itself in each quadrant of the circle whereas the pattern shown repeats itself only in each semicircle. It will be noted that the pattern shown in dashed lines for the four units without the cylinder is cyclic for each quadrant. When a dipole is placed near a cylinder, radiation takes place in the direction of the dipole axis even though the radiation in this direction from the dipole alone is zero. The field in this direction is due to currents set up in the surface of the cylinder. When two diametrically opposite dipoles are fed in phase this is also true. The currents responsible for this radiation in the direction of the axes of the dipole pair are not in phase with the dipole currents which cause them. Let us call one pair of opposite dipoles *A* and the other *B*, and assume the current in *A*

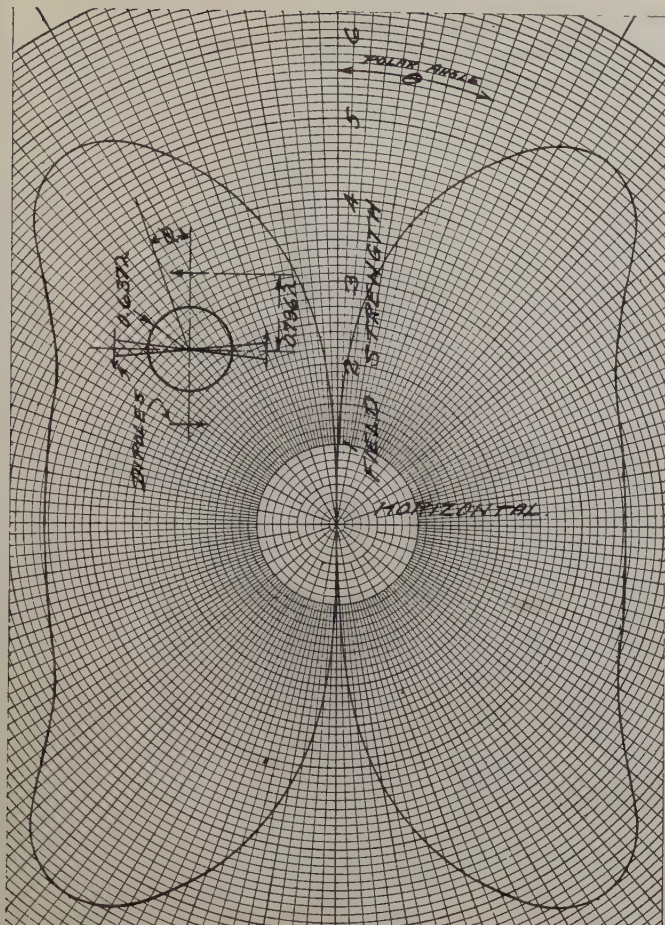


Fig. 20—Four horizontal dipoles and cylinder. (B) All dipoles fed in phase. Vertical pattern. In phase halfway between pairs ($\phi = 45$ degrees). Horizontal component.

of zero phase and the current in pair *B* of $+90$ degrees phase. The current in the cylinder responsible for radiation in the direction of the axes of *A*, as already stated will have a phase angle which we may designate as ψ . The radiation due to pair *B* in this direction is proportional to the current in *B* but the current leads that in *A* by 90 degrees. For this direction the effective current may be written as $I_1 = FZ\psi + j1$. In the direction of the axis of *B* we then have $I_2 = jFZ\psi + 1$. The magnitudes of these two effective currents are not generally equal since $|I_1|^2 = 1 + F^2 + 2F\sin\psi$ and $|I_2|^2 = 1 + F^2 - 2F\sin\psi$. Thus the radiation in these two perpendicular directions generally is not equal. In attempting to give a simple explanation for this peculiarity in the pattern we have neglected the current in the cylinder due to pair *B* which is effective in producing radiation in the direction of the axes of pair *A* and passed over some other matters rather loosely.

It will be noted that, under the assumed feeding relations, the pattern for the dipoles with the cylinder is much better than for the four dipoles alone. Although the radiation diagram departs considerably from a circle it should be fairly satisfactory for broadcast purposes. In order for such a system to be efficient the radiation at high angles must be reasonably low. That

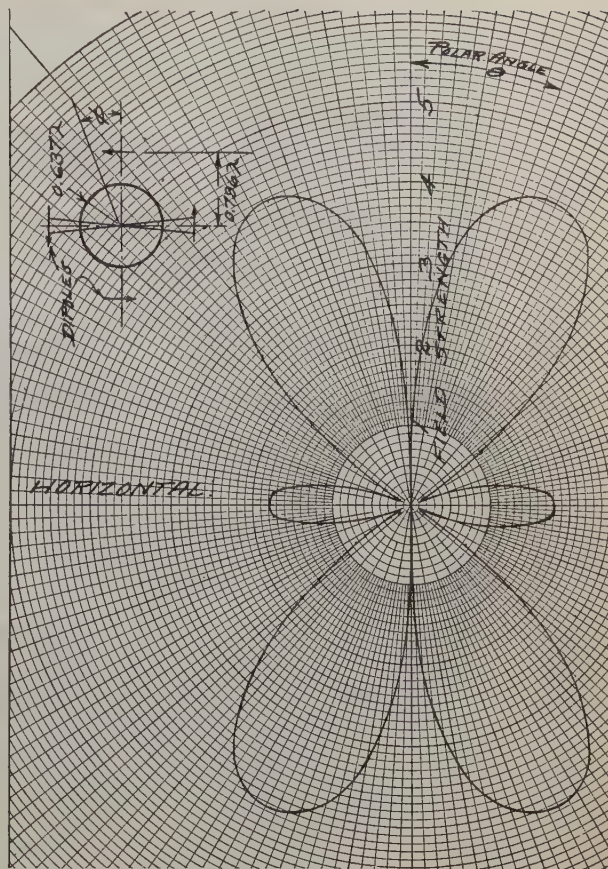


Fig. 21—Four horizontal dipoles and cylinder. (C). All dipoles fed in phase. Vertical pattern in plane at 22.5 degrees to plane of pair. ($\phi = 22.5$ degrees.) Horizontal component.

such is not the case will become evident upon inspection of Figs. 23, 24, and 25.

Fig. 23 shows the pattern in a vertical plane passing through the pair of dipoles fed in leading quarter phase. The energy radiated at angles in the vicinity of 20 degrees to the vertical is more than five times that radiated horizontally. In the vertical plane passing halfway between the dipole pairs the energy radiated in a direction 35 degrees to the vertical is nearly three times that radiated horizontally, the pattern for this vertical plane being shown in Fig. 25. The radiation in the vertical plane passing through the pair in lagging phase is a maximum in the vicinity of 60 degrees to the vertical and the energy is nearly twice that radiated horizontally (see Fig. 24). It is thus evident that two tiers are necessary in order to obtain an efficient antenna of this type. If two tiers are spaced vertically by a distance of 0.55 wavelength so as to cancel radiation at and near a vertical angle of 25 degrees an efficient system is obtained.

(c) Four Horizontal Dipoles Fed in Quarter Phase Rotation

The horizontal pattern for this condition is shown in Fig. 26. Here we have a pattern which repeats itself in each quadrant but is not symmetrical for right- and left-hand rotation. With this type of feed an observer looking in from outside the cylinder would have no way

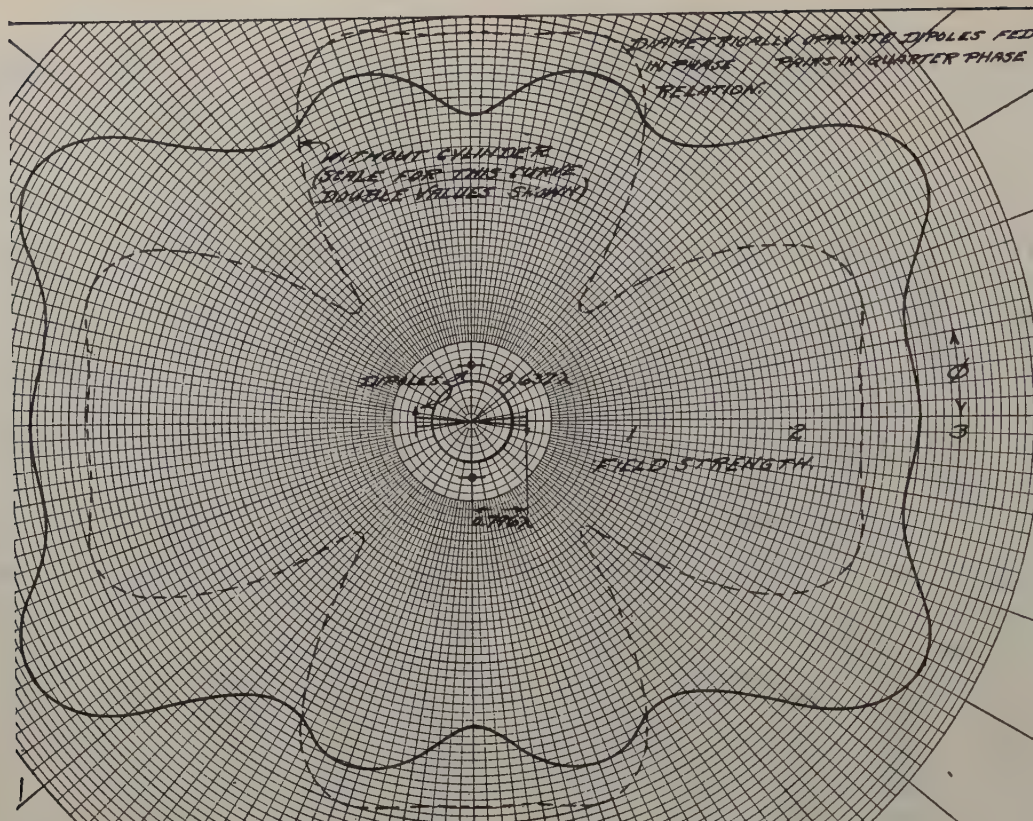


Fig. 22—Four horizontal dipoles and cylinder. (D). Horizontal pattern.

of distinguishing one quadrant from another so that the radiation pattern would necessarily be cyclic for each quadrant. Since such an observer would theoretically be able to distinguish between right- and left-hand phase rotation it would not be unreasonable to expect the pattern to be dissimilar for right- and left-hand rotation. The pattern for the same four dipoles without the cylinder which is shown in dashed lines is symmetrical for right- and left-hand rotation. The horizontal pattern for this method of feed is, from a broadcast viewpoint, considerably inferior to that discussed under (b) and we have not taken the trouble to calculate the corresponding vertical patterns for this condition.

HORIZONTAL DIPOLES AROUND CYLINDER— DIPOLE AXES RADIAL

For broadcasting the only useful arrangements of this type are arrays fed in phase rotation. A substantially circular pattern may be obtained with 4 dipoles when the radius of the array is less than 0.14 wavelength. If the inner conductors of concentric transmission lines are allowed to project a short distance outwardly from the cylinder as in Fig. 27 the system is in effect equivalent to an array of dipoles in close proximity to the cylinder.

The horizontal pattern for a 4-phase array like that of the figure when the diameter of the cylinder is 0.48 wavelength is shown in Fig. 28. It will be noted that there is considerable variation in the field strength with direction. For this diameter a 6-unit, 6-phase array would be satisfactory.

GENERAL THEORY

The majority of engineers probably do not realize that rigorous solutions of the fundamental electromagnetic laws are only possible under a very limited number of highly idealized conditions. Most of the so-called laws of electrical engineering are only approximations which become increasingly more inaccurate as the frequencies involved become higher and higher or, more specifically, as the sizes of the elements concerned become greater in terms of the wavelengths involved. At the other extreme we have the laws of geometrical optics which are reasonably accurate only when the dimensions concerned are of the order of hundreds of wavelengths or greater. The conditions in many of the problems connected with ultra-high-frequency radio practice lie within the region between the two extremes mentioned and neither electrical engineering methods nor the laws of geometrical optics can be relied upon to predict results. The only safe procedure then is either to try to find a solution of Maxwell's equations under idealized conditions which approximate actual conditions or to forget all theory and rely entirely upon experimental measurements.

If all the currents in a system of conductors are known the fields throughout all space may, theoretically at least, be immediately determined. For many antenna problems we have a fairly reliable knowledge of the currents and make use of this principle. For example we assume the current in a thin-wire half-wave dipole to be of sine-wave form and upon this assumption determine

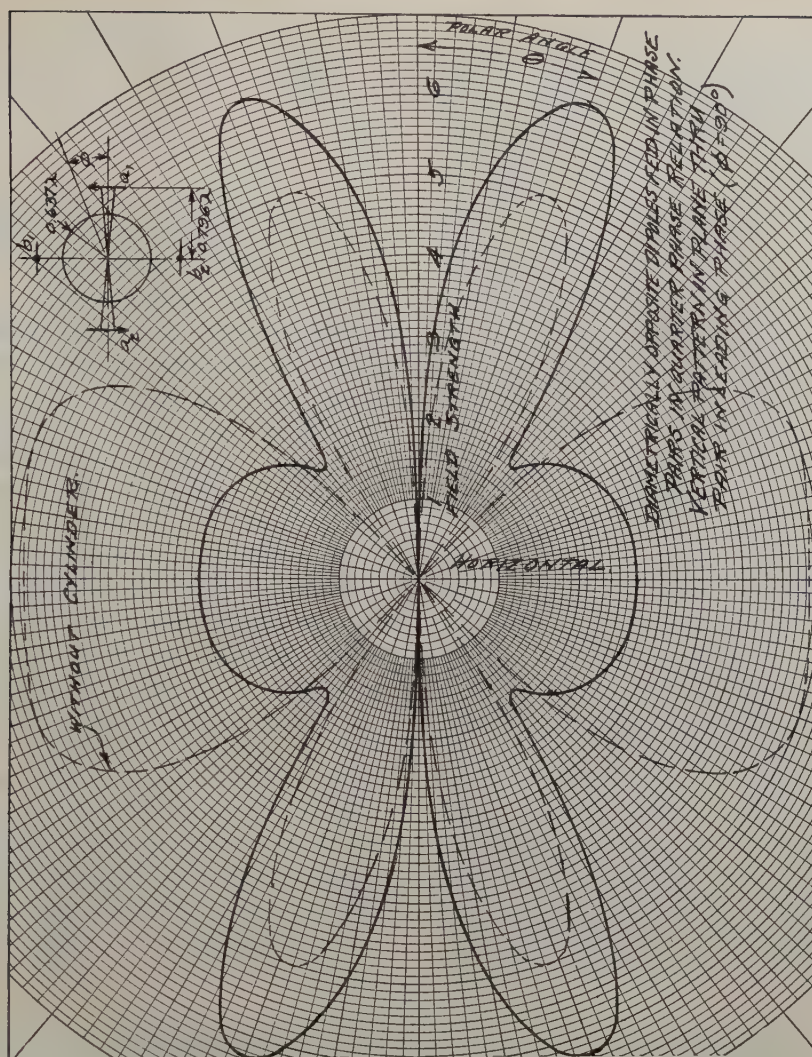


Fig. 23—Four horizontal dipoles and cylinder. (E).

the fields. Both rigorous theory and measurements indicate that such an assumption is sufficiently accurate for most purposes. When a dipole is located near a cylinder we are in complete ignorance of the currents flowing on the cylinder surface so that this method is useless.

All electromagnetic fields in space must be waves consistent with Maxwell's laws. If we assume all bodies to be perfectly conducting, a legitimate assumption for high frequencies since the radiated energy is usually many times the energy converted into heat, the tangential component of electric force at the surfaces of the bodies must be zero since a perfect conductor can support no voltage. This knowledge alone must serve as the foundation for the solution of this type of problem.

Consider a horizontal dipole located near a very tall conducting cylinder. For a given current in the dipole we may determine the field everywhere in space due to the dipole alone and will henceforth call this the primary field. This primary field is the driving force for currents around the conducting cylinder. These currents in the cylinder set up a secondary electric field in a more or less similar manner to the counter electromotive force in an electric motor. This secondary electric force must

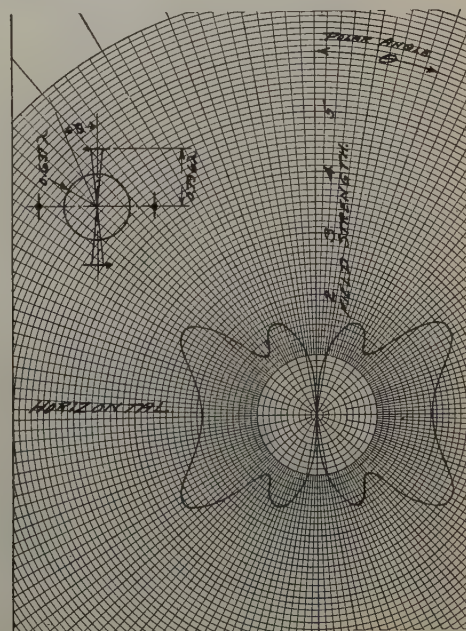


Fig. 24—Four horizontal dipoles and cylinder. (F). Diametrically opposite dipoles fed in phase. Pairs in quarter-phase relation. Vertical pattern in plane through lagging pair. ($\phi=0$.)

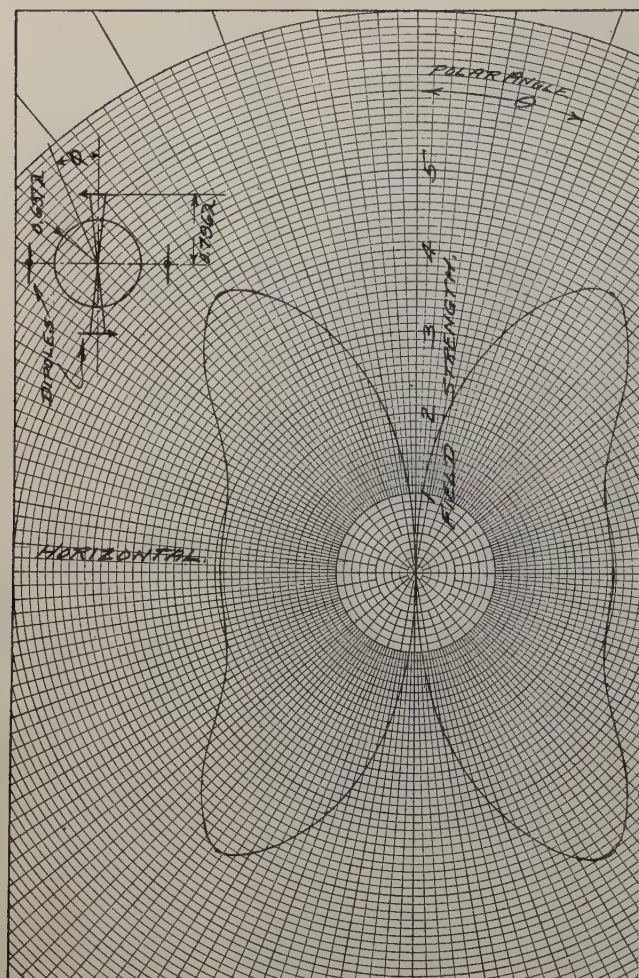


Fig. 25—Four horizontal dipoles and cylinder. (G). Diametrically opposite dipoles fed in phase. Pairs in quarter-phase relation. Vertical pattern in plane halfway between pairs. ($\phi=45$ degrees.)

exactly counterbalance the primary electric force everywhere on the surface of the cylinder and result in zero total electric force tangential to the cylinder. In accordance with Maxwell's laws this secondary field must be constituent of a secondary system of electromagnetic waves diverging outwardly from the cylindrical surface. The electric and magnetic forces of this system of waves must follow the laws of cylindrical symmetry; i.e., the waves are cylindrical. The secondary electromagnetic field may be expressed as the sum of a number of waves, the intensity of the field of each one of which must undergo a cyclic variation expressed in terms of the sine and/or cosine of an integral multiple of the horizontal direction angle, and at the same time must vary with radial distance in a manner consistent with the fundamental electromagnetic laws.

In order to determine the amplitude of each of the secondary waves it is first necessary to break up the primary field from the dipole into a number of cylindrical waves having the axis of the cylinder as their axis of symmetry. When the mathematical expression for the primary field is so expanded the result is an infinite series wherein each term contains an infinite integral. In other words we have an infinite sum of an infinite sum of waves of infinitesimal amplitude. To avoid the

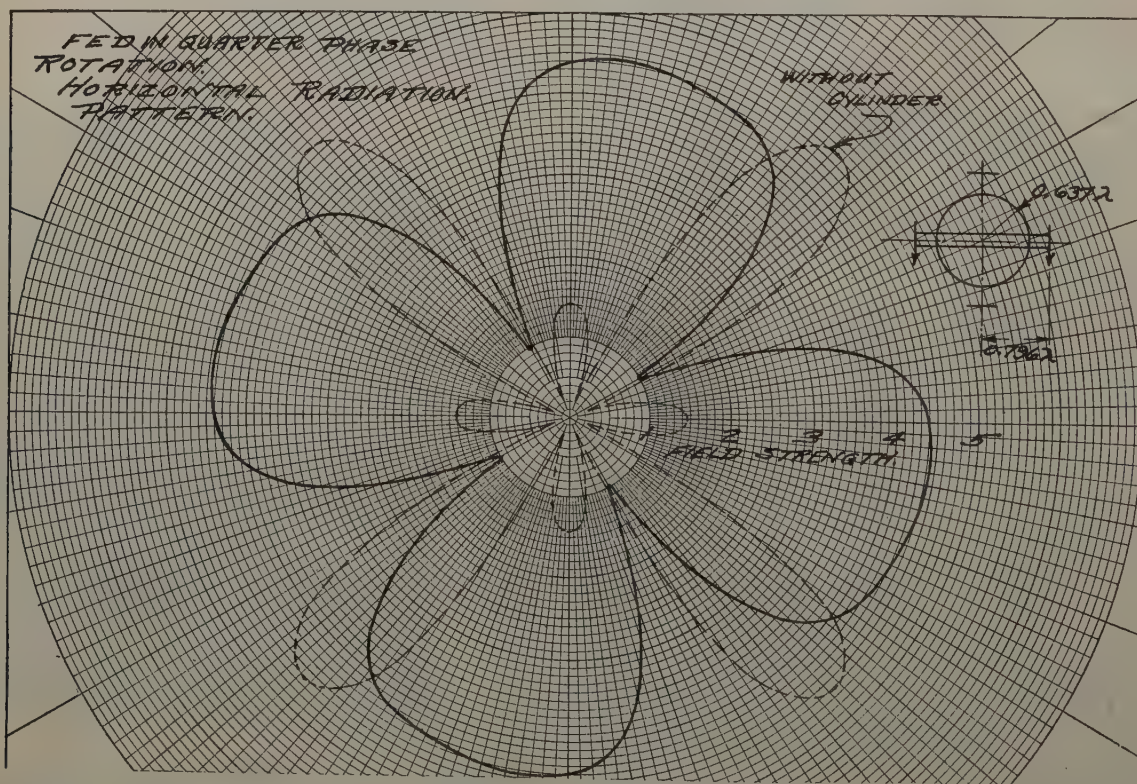


Fig. 26—Four horizontal dipoles and cylinder. (H).

difficulties inherent in working with infinite integrals we may make use of the reciprocity law in the following way: Imagine a dipole (1) located at a great distance from the cylinder and a second dipole (2) located near the cylinder. The wave from (1) is essentially plane upon arrival at the cylinder. In accordance with the reciprocity law if a current of 1 ampere in (1) results in a certain voltage at the terminals of (2) we may interchange the position of current and voltage without altering the result. The plane traveling wave from (1) may be expressed as an infinite sum of standing cylindrical waves. This series is devoid of infinite integrals. Now, by equating the sum of the primary and secondary tangential electric forces of each wave of the infinite series of waves to zero at the surface of the cylinder we obtain the amplitudes of each of the secondary electromagnetic waves. Then by applying the reciprocity principle we obtain an expression which gives us the total radiation field from the dipole and cylinder. If we locate dipole (2) in various positions around the cylinder and apply the reciprocity principle we may immediately obtain the directive pattern for a dipole located at any specified position near the cylinder. Having obtained the expression for the field due to one dipole and the cylinder we may add the fields due to any number of other dipoles including the effect of the cylinder, these additional dipoles being fed in any desired phase relation and located at any specified position and thus obtain the over-all radiation characteristic.

In making use of the reciprocity theorem to avoid infinite integrals in the series we lose a knowledge of currents on the cylinder surface. However, if we assume a high stack of closely spaced dipoles, rather than a single unit, the expression for the primary field of the near-by source when expanded into a Fourier series is

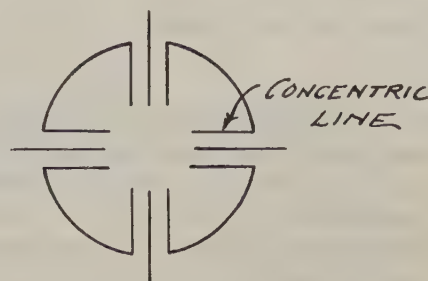


Fig. 27—Radial radiators and cylinder.

devoid of infinite integrals. The cylinder currents may then be obtained without difficulty.

As described the processes would appear to be simple straightforward procedures. Unfortunately, the mathematical technique involved is considerable. The mathematical development shown should be in sufficient detail to be clear to one having some familiarity with the vector calculus, partial differential equations and the theory of Bessel functions. A bibliography of the publications referred to by the author is given. There are, no doubt, many other references but only those available to the author are given.

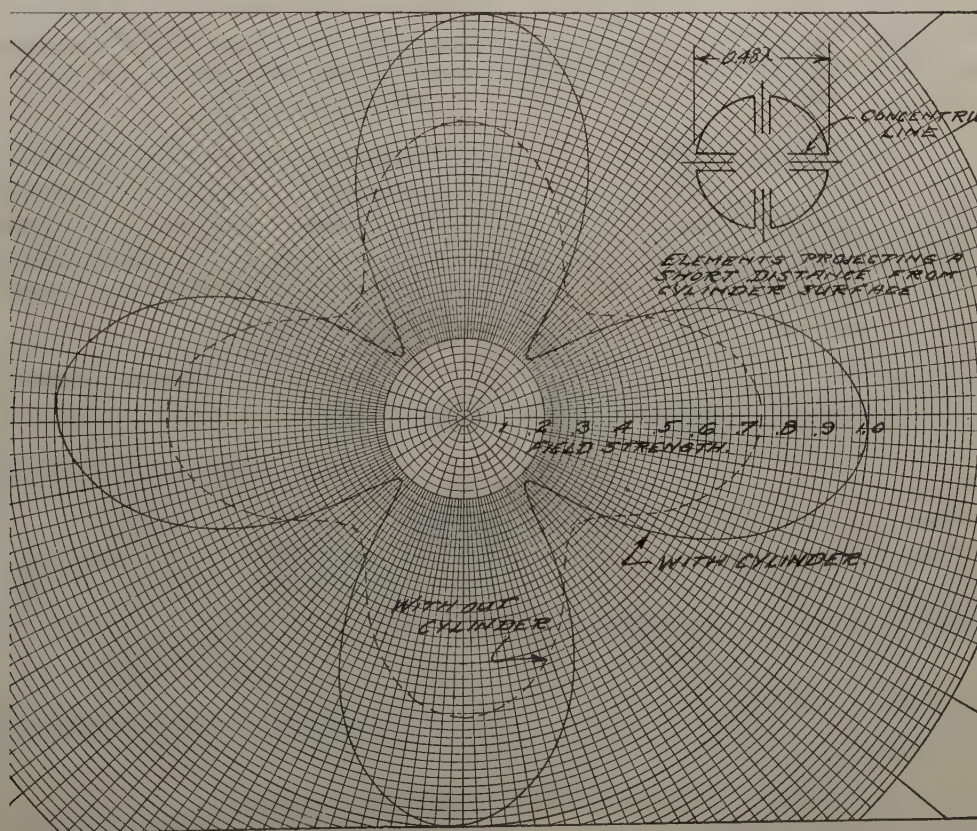


Fig. 28—Four radial horizontal dipoles and cylinder units fed in phase rotation.

FORMULAS FOR RADIATION PATTERNS— ARRAYS AROUND CYLINDERS

The following table of formulas covers most arrays likely to be used in practice.

Symbols

a = radius of cylinder

b = radius of radiator circle

$k = 2\pi/\lambda$

$j = \sqrt{-1}$

$J_n(\)$ = n th order Bessel function of first kind

$U_n(\)$ = n th order Hankel function of second kind

$J'_n(\)$, $U'_n(\)$ = derivatives with respect to their arguments

ϵ = Newman's number = 1 for $n=0$ and 2 for $n=2, 3, 4$, etc.

θ = polar angle to vertical axis

ϕ = horizontal angle (longitude)

E_ϕ = electric field in direction ϕ (horizontal)

E_θ = electric field in direction θ (vector in vertical plane)

V_n , W_n , B_n , and D_n are expressions involving n th order Bessel functions as given with the single-unit formulas for each type of array

HORIZONTAL DIPOLES—AXES CIRCUMFERENTIAL

One Unit

$$E_\phi = - \left[jW_0 + 2j \sum_{n=0}^{\infty} (j)^n W_n \cos n\phi \right] \quad (1)$$

where

$$W_n = J'_n(kb \sin \theta) - \{J'_n(ka \sin \theta)/U'_n(ka \sin \theta)\} U'_n(kb \sin \theta)$$

$$E_\theta = (-j2 \cos \theta / kb \sin \theta) \sum_{n=1}^{\infty} (j)^n \cdot n \cdot V_n \sin n\phi. \quad (2)$$

where

$$V_n = [J_n(kb \sin \theta) - \{J_n(ka \sin \theta)/U_n(ka \sin \theta)\} U_n(kb \sin \theta)]$$

Two Units—Diametrically Opposite, In Phase

$$E_\phi = -2j \{W_0 - 2W_2 \cos 2\phi + 2W_4 \cos 4\phi - \dots\} \quad (3)$$

$$E_\theta = (j4/kb \sin \theta) \{2V_2 \sin 2\phi - 4V_4 \sin 4\phi + 6V_6 \sin 6\phi - \dots\} \quad (4)$$

Two Units—Phase Opposition

$$E_\phi = 4 \{W_1 \cos \phi - W_3 \cos 3\phi + W_5 \cos 5\phi - \dots\} \quad (5)$$

$$E_\theta = (4 \cos \theta / kb \sin \theta) \{V_1 \sin \phi - 3V_3 \sin 3\phi + 5V_5 \sin 5\phi - \dots\}. \quad (6)$$

Three Units—In Phase

$$E_\phi = -j3 \{W_0 - j2W_3 \cos 3\phi - 2W_6 \cos 6\phi + \dots + (j)^{3n} \cdot 2W_{3n} \cos 3n\phi + \dots\} \quad (7)$$

$$E_\theta = (-6 \cos \theta / kb \sin \theta) \{3W_3 \sin 3\phi - j6V_6 \sin 6\phi - 9V_9 \sin 9\phi + \dots + 3n(j)^{3n} V_{3n} \sin 3n\phi + \dots\} \quad (8)$$

Three Units—Phase Rotation (3-Phase)

$$E_\phi = 3 \exp(j\phi) \{W_1 + jW_2 \exp(-j3\phi) - jW_4 \exp(j3\phi) + W_5 \exp(-j6\phi) - W_7 \exp(j6\phi) + \dots\} \quad (9)$$

$$E_\theta = -j(3 \cos \theta / kb \sin \theta) \exp(j\phi) \{V_1 - j2V_2 \exp(-j3\phi) + j4V_4 \exp(j3\phi) - 5V_5 \exp(-j6\phi) - V_7 \exp(j6\phi) + \dots\} \quad (10)$$

Four Units—In Phase

$$E_\phi = -j4 \{W_0 + 2W_4 \cos 4\phi + 2W_8 \cos 8\phi + \dots\} \quad (11)$$

$$E_\theta = (-j8 \cos \theta / kb \sin \theta) \{4V_4 \sin 4\phi + 8V_8 \sin 8\phi + 12V_{12} \sin 12\phi + \dots\}. \quad (12)$$

Four Units—Phase Rotation (4-Phase)

$$E_\phi = 4 \exp(j\phi) \{W_1 - W_3 \exp(-j4\phi) + W_5 \exp(j4\phi) - W_7 \exp(-j8\phi) + W_9 \exp(j8\phi) - \dots\} \quad (13)$$

$$E_\theta = (-j4 \cos \theta / kb \sin \theta) \exp(j\phi) \{V_1 + 3V_3 \exp(-j4\phi) + 5V_5 \exp(j4\phi) + 7V_7 \exp(-j8\phi) + 9V_9 \exp(j8\phi) + \dots\} \quad (14)$$

Four Units—Units of Pair in Phase, Pair in Quarter Phase

$$E_\phi = -j2\sqrt{2} \exp(j\pi/4) \{W_2 \cos 2\phi + j2W_4 \cos 4\phi + 2W_6 \cos 6\phi + \dots\} \quad (15)$$

$$E_\theta = (4\sqrt{2}/kb \sin \theta) \exp(j\pi/4) \cos \theta \{2V_2 \sin 2\phi - j4V_4 \sin 4\phi + 6V_6 \sin 6\phi - \dots\}. \quad (16)$$

Six Units—In Phase

$$E_\phi = -6j \{W_0 + 2W_6 \cos 6\phi + 2W_{12} \cos 12\phi + \dots\} \quad (17)$$

$$E_\theta = (-j12 \cos \theta / kb \sin \theta) \{6V_6 \sin 6\phi + 12V_{12} \sin 12\phi + \dots\}. \quad (18)$$

Six Units—Phase Rotation (6-Phase)

$$E_\phi = 6 \exp(j\phi) \{W_1 + W_5 \exp(-j6\phi) + W_7 \exp(j6\phi) + W_{11} \exp(-j12\phi) + W_{13} \exp(j12\phi) + \dots\} \quad (19)$$

$$E_\theta = (-j6 \cos \theta / kb \sin \theta) \exp(j\theta) \{V_1 - 5V_5 \exp(-j6\phi) + 7V_7 \exp(j6\phi) - 11V_{11} \exp(-j12\phi) + 13V_{13} \exp(j12\phi) + \dots\}. \quad (20)$$

Eight Units—In Phase

$$E_\phi = -j8 \{W_0 + 2W_8 \cos 8\phi + 2W_{16} \cos 16\phi + \dots\} \quad (21)$$

$$E_\theta = (-j8 \cos \theta / kb \sin \theta) \{8V_8 \sin 8\phi + 16V_{16} \sin 16\phi + \dots\}. \quad (22)$$

Eight Units—Phase Rotation (8-Phase)

$$E_\phi = 8 \exp(j\phi) \{W_1 - W_7 \exp(-j8\phi) + W_9 \exp(j8\phi) - W_{15} \exp(-j16\phi) + W_{17} \exp(j16\phi) + \dots\} \quad (23)$$

$$E_\theta = (-8j \cos \theta / kb \sin \theta) \exp(j\phi) \{V_1 + 7V_7 \exp(-j8\phi) + 9V_9 \exp(j8\phi) + 15V_{15} \exp(-j16\phi) + 17V_{17} \exp(j16\phi) + \dots\}. \quad (24)$$

HORIZONTAL DIPOLES—AXES RADIAL

Single Unit

$$E_\phi = (-j2/kb \sin \theta) \sum_{n=1}^{\infty} (j)^n \cdot n \cdot B_n \sin n\phi \quad (25)$$

where

$$B_n = [J_n(kb \sin \theta) - \{J'_n(ka \sin \theta)/U'_n(ka \sin \theta)\} U_n(kb \sin \theta)]$$

$$E_\theta = j \cos \theta \left[D_0 + 2 \sum_{n=1}^{\infty} (j)^n D_n \cos n\phi \right] \quad (26)$$

where

$$D_n = [J'_n(kb \sin \theta) - \{J_n(ka \sin \theta)/U_n(ka \sin \theta)\} U'_n(kb \sin \theta)]$$

Two Units—In Phase

$$E_\phi = (j4/kb \sin \theta) \{2B_2 \sin 2\phi - 4B_4 \sin 4\phi + 6B_6 \sin 6\phi - \dots\} \quad (27)$$

$$E_\theta = j2 \cos \theta \{ D_0 + 2D_2 \cos 2\phi + 2D_4 \cos 4\phi + \dots \}. \quad (28)$$

Two Units—Phase Opposition

$$E_\phi = (4/kb \sin \theta) \{ B_1 \sin \phi - 3B_3 \sin 3\phi + 5B_5 \sin 5\phi - \dots \} \quad (29)$$

$$E_\theta = -4 \cos \theta \{ D_1 \cos \phi - D_3 \cos 3\phi + D_5 \cos 5\phi - \dots \} \quad (30)$$

Three Units—In Phase

$$E_\phi = (6/kb \sin \theta) \{ 3B_3 \sin 3\phi + j6B_5 \sin 5\phi + 9B_7 \sin 7\phi + 12B_9 \sin 9\phi + \dots \} \quad (31)$$

$$E_\theta = j3 \cos \theta \{ D_0 - j2D_2 \cos 2\phi - 2D_4 \cos 4\phi + j2D_6 \cos 6\phi + \dots \}. \quad (32)$$

Three Units—Phase Rotation (3-Phase)

$$E_\phi = (-j3/kb \sin \theta) \exp(j\phi) \{ B_1 - j2B_2 \exp(-j3\phi) - j4B_4 \exp(j3\phi) - 5B_5 \exp(-j6\phi) - 7B_7 \exp(j6\phi) - j \dots \} \quad (33)$$

$$E_\theta = -3 \cos \theta \exp(j\phi) \{ D_1 + jD_2 \exp(-j3\phi) - jD_4 \exp(j3\phi) + D5 \exp(-j6\phi) + D7 \exp(j6\phi) + j \dots \}. \quad (34)$$

Four Units—In Phase

$$E_\phi = (-j8/kb \sin \theta) \{ 4B_4 \sin 4\phi + 8B_8 \sin 8\phi + \dots \} \quad (35)$$

$$E_\theta = j4 \cos \theta \{ D_0 + 2D_4 \cos 4\phi + 2D_8 \cos 8\phi + \dots \}. \quad (36)$$

Four Units—Units of Pair in Phase, Pairs in Quarter Phase

$$E_\phi = (4\sqrt{2} e^{j(\pi/4)}/kb \sin \theta) \{ 2B_2 \sin 2\phi - j4B_4 \sin 4\phi + 6B_6 \sin 6\phi - j8B_8 \sin 8\phi + \dots \} \quad (37)$$

$$E_\theta = j2\sqrt{2} e^{j(\pi/4)} \cos \theta \{ D_0 + j2D_2 \cos 2\phi + 2D_4 \cos 4\phi + j \dots \}. \quad (38)$$

Six Units—In Phase

$$E_\phi = (-j12/kb \sin \theta) \{ 6B_6 \sin 6\phi + 12B_{12} \sin 12\phi + \dots \} \quad (39)$$

$$E_\theta = j6 \cos \theta \{ D_0 + 2D_6 \cos 6\phi + 2D_{12} \cos 12\phi + \dots \}. \quad (40)$$

Six Units—Phase Rotation (6-Phase)

$$E_\phi = (-j6/kb \sin \theta) \exp(j\phi) \{ B_1 - 5B_5 \exp(-j6\phi) - 7B_7 \exp(j7\phi) + \dots \} \quad (41)$$

$$E_\theta = -6 \cos \theta \exp(j\phi) \{ D_1 + D_5 \exp(-j6\phi) + D_7 \exp(j7\phi) + \dots \} \quad (42)$$

Eight Units—In Phase

$$E_\phi = (-j16/kb \sin \theta) \{ 8B_8 \sin 8\phi + 16B_{16} \sin 16\phi + \dots \} \quad (43)$$

$$E_\theta = j8 \cos \theta \{ D_0 + 2D_8 \cos 8\phi + 2D_{16} \cos 16\phi + \dots \} \quad (44)$$

Eight Units—Phase Rotation (8-Phase)

$$E_\phi = (-j8/kb \sin \theta) \exp(j\phi) \{ B_1 + 7B_7 \exp(-j7\phi) + 9B_9 \exp(-j7\phi) + 15B_{15} \exp(j16\phi) + \dots \} \quad (45)$$

$$E_\theta = 8 \cos \theta \exp(j\phi) \{ D_1 + D_7 \exp(-j7\phi) + D_9 \exp(-j7\phi) + D_{15} \exp(j16\phi) + \dots \}. \quad (46)$$

VERTICAL DIPOLES

One Unit

$$E_\theta = \sin \theta \left[V_0 + 2 \sum_{n=1}^{\infty} (j)^n V_n \cos n\phi \right] \quad (47)$$

where

$$V_n = [J_n(kb \sin \phi) - \{ J_n(ka \sin \theta) / U_n(ka \sin \theta) \} U_n(kb \sin \theta)].$$

Two Units—In Phase

$$E_\theta = 2 \sin \theta [V_0 + 2V_2 \cos 2\phi + 2V_4 \cos 4\phi + \dots]. \quad (48)$$

Two Units—Phase Opposition

$$E_\theta = j4 \sin \theta [V_1 \cos \phi - V_3 \cos 3\phi + V_5 \cos 5\phi - \dots]. \quad (49)$$

Three Units—In Phase

$$E_\theta = 3 \sin \theta [V_0 + 2V_2 \cos 2\phi + 2V_4 \cos 4\phi + \dots]. \quad (50)$$

Three Units—Phase Rotation

$$E_\theta = 3 \sin \theta \exp(j\phi) [V_1 + jV_2 \exp(-j3\phi) - jV_4 \exp(j3\phi) + V_5 \exp(-j6\phi) - V_7 \exp(j7\phi) + \dots] \quad (51)$$

Four Units—In Phase

$$E_\theta = 4 \sin \theta [V_0 + 2V_4 \cos 4\phi + 2V_8 \cos 8\phi + \dots]. \quad (52)$$

Four Units—Phase Rotation (4-Phase)

$$E_\theta = j4 \sin \theta \exp(j\phi) \{ V_1 - V_3 \exp(-j4\phi) + V_5 \exp(j4\phi) - V_7 \exp(-j8\phi) + V_9 \exp(j8\phi) - \dots \}. \quad (53)$$

Four Units—Units of Pair in Phase, Pairs in Quarter Phase

$$E_\theta = 2\sqrt{2} \exp(j(\pi/4)) \sin \theta \{ V_2 \cos 2\phi + j2V_4 \cos 4\phi + 2V_6 \cos 6\phi + j2V_8 \cos 8\phi + \dots \}. \quad (54)$$

Six Units—In Phase

$$E_\theta = 6 \sin \theta \{ V_0 + 2V_6 \cos 6\phi + 2V_{12} \cos 12\phi + \dots \}. \quad (55)$$

Six Units—Phase Rotation (6-Phase)

$$E_\theta = j6 \sin \theta \exp(j\phi) \{ V_1 + V_5 \exp(-j6\phi) + V_7 \exp(j6\phi) + V_{11} \exp(-j12\phi) + V_{13} \exp(j12\phi) + \dots \}. \quad (56)$$

Eight Units—In Phase

$$E_\theta = 8 \sin \theta \{ W_0 + 2W \cos 8\phi + 2W_{16} \cos 16\phi + \dots \}. \quad (57)$$

Eight Units—Phase Rotation (8-Phase)

$$E_\theta = j8 \sin \theta \exp(j\phi) \{ V_1 - V_7 \exp(-j8\phi) + V_9 \exp(j8\phi) - V_{15} \exp(-j16\phi) + V_{17} \exp(j16\phi) + \dots \}. \quad (58)$$

MULTITIER ARRAYS OF ALL TYPES

For an array of n tiers fed in phase multiply the field from one tier by $\{\sin(n/2kS \cos \theta)/\sin(kS/2 \cos \theta)\}$, where S is the spacing and θ the angle to the vertical.

MATHEMATICAL THEORY

Fig. 29 shows the system of co-ordinates which will be used and is self-explanatory. For convenience a polar angle θ , properly belonging to a spherical co-ordinate system, is used together with the usual cylindrical co-ordinates. In order to carry out the method of solution which has been outlined we must first start with the fundamental differential equations of electromagnetic theory. If, in accordance with standard engineering practice, we let the time function be represented by the real part of $\exp(j\omega t)$ the fundamental laws¹ for free space become

$$c \operatorname{curl} \bar{H} = (\delta \bar{E} / \delta t) \text{ or } \bar{E} = (-j/k) \operatorname{curl} \bar{H} \quad (59)$$

$$c \operatorname{curl} \bar{E} = (-\delta \bar{H} / \delta t) \text{ or } \bar{H} = (j/k) \operatorname{curl} \bar{E} \quad (60)$$

$$\operatorname{div} \bar{E} = \operatorname{div} \bar{H} = 0 \quad (61)$$

where \bar{E} = electric vector

\bar{H} = magnetic vector

¹ Heaviside-Lorentz units are used for simplicity.

c = velocity of light = 3×10^{10} centimeters per second

ω = angular frequency

$j = \sqrt{-1}$

and $k = \omega/c = 2\pi/\lambda$, λ being the wavelength in centimeters.

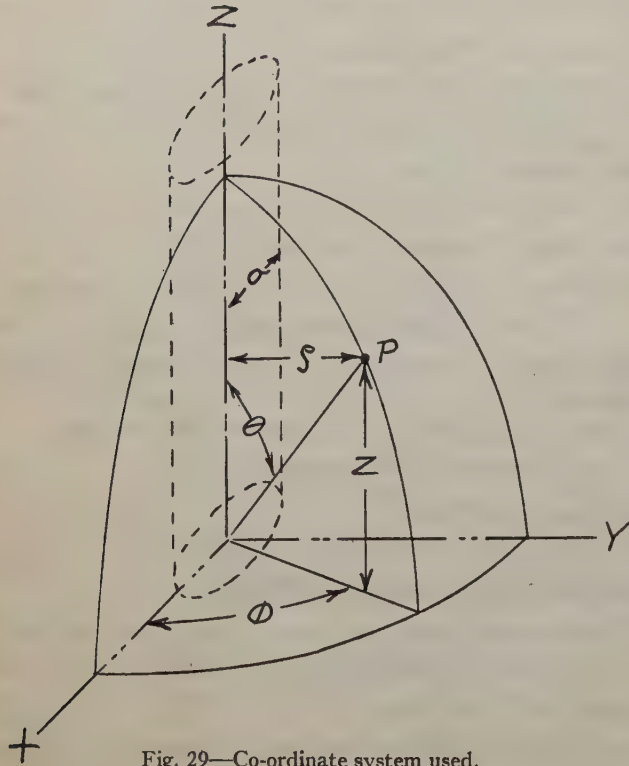


Fig. 29—Co-ordinate system used.

By differentiating and combining the above relations we obtain the vector-wave equations

$$\nabla^2 \bar{E} + k^2 \bar{E} = 0 \quad (62)$$

$$\nabla^2 \bar{H} + k^2 \bar{H} = 0. \quad (63)$$

Let us first consider the scalar-wave equation

$$\nabla^2 \psi + k^2 \psi = 0 \quad (64)$$

which, written in cylindrical co-ordinates, becomes

$$\frac{\partial^2 \psi}{\partial \rho^2} + \frac{1}{\rho} \frac{\partial \psi}{\partial \rho} + \frac{1}{\rho^2} \frac{\partial^2 \psi}{\partial \phi^2} + \frac{\partial^2 \psi}{\partial z^2} + k^2 \psi = 0. \quad (65)$$

We shall not take the time to consider the mathematical details involved in the solution of this partial differential equation.²⁻⁵ A general solution which represents diverging waves is

$$\psi = \sum_{n=0}^{\infty} U_n(k\rho \sin \theta) [A_n \cos(kz \cos \theta) + B_n \sin(kz \sin \theta)] \cdot [C_n \cos n\phi + D_n \sin \phi] \quad (66)$$

where U_n is the Hankel function of the second kind of order n , which is usually written⁶ as $H_n^{(2)}$ but which has

² W. E. Byerly, "Fourier Series and Spherical Harmonics," Ginn and Co., New York, N. Y., 1893.

³ F. S. Woods, "Advanced Calculus," Ginn and Co., New York, N. Y., 1926.

⁴ H. Bateman, "Electrical and Optical Wave Motion," Cambridge University Press, London, England, 1915.

⁵ E. T. Whittaker and G. N. Watson, "Modern Analysis," Cambridge University Press, London, England, 1927.

⁶ E. Jahnke and F. Emde, "Tables of Functions," B. G. Teubner, Leipzig, Germany, 1933 and 1938.

been designated here as U_n to avoid confusion with the magnetic vector \bar{H} .

A_n, B_n, C_n, D_n are arbitrary constants.

" n " in connection with the problem at hand, must be an integral number or zero.

If we replace the Hankel function in the above relation by a Bessel function of either the first or second kind we have a solution of the wave equation representing standing cylindrical waves.

Now suppose we multiply the scalar-wave function ψ by a constant vector in the z direction (vertical). We then have a solution of the vector-wave equation. This vector function, however, cannot in general represent either the electric or magnetic force of a possible electromagnetic wave since it violates the continuity law, i.e., the divergence is not zero. Nevertheless it is very useful. If we let the electric force (E) equal the curl of this function we have an electromagnetic wave consistent with the fundamental laws. This wave has no vertical component of electric force. Another electromagnetic wave may be obtained from the same vector function by letting the magnetic force H be equal to curl of this function. This wave has no vertical component of magnetic force. The most general type of electromagnetic field may be considered as a combination of these two types of waves.

Since the amplitude of the vector function is entirely arbitrary let us for convenience designate the function in accordance with its use. When the electric field is equal to its curl we shall call the function the "electric vector potential" whereas when the magnetic field is obtained from it by curling we will use the term "magnetic vector potential." It should be remembered that both types of potentials are the same function excepting for differences in the arbitrary constants. Calling the first type \bar{F} and the second \bar{A} we may write the following relations giving the electric and magnetic forces in the most general type of electromagnetic field as follows:

$$\bar{E} = (-J/k) \text{curl} (\text{curl} \bar{A}) - \text{curl} \bar{F} \\ = (-j/k)(\text{grad div} \bar{A} + k^2 \bar{A}) - \text{curl} \bar{F} \quad (67)$$

$$\bar{H} = \text{curl} \bar{A} - (j/k) \text{curl} (\text{curl} \bar{F}) \\ = \text{curl} \bar{A} - (j/k)(\text{grad div} \bar{F} + k^2 \bar{F}). \quad (68)$$

A. Horizontal Dipole and Cylinder—Dipole Axis Circumferential

At a great distance from the vertical cylinder and in the xz plane in a polar direction θ let us assume a horizontal dipole, i.e., a dipole with its axis perpendicular to the xz plane. The electric field from such a dipole may be represented in the vicinity of the cylinder by

$$\bar{E}_y = \exp[j(kx \sin \theta + kz \cos \theta)] \\ = \exp[j(k\rho \sin \theta \cos \phi + kz \cos \theta)] \quad (69)$$

if we leave out the amplitude factor and use the origin of co-ordinates as our reference point for phase.

Since no vertical component of electric force exists the electric field of this wave can be derived from a vector function \bar{F} in accordance with the relation,

$$\bar{E}_y = -\text{curl}_y \bar{F}_z = \bar{E}_\phi \cos \phi + \bar{E}_\rho \sin \phi. \quad (70)$$

Hence $\delta \bar{F} / \delta x = \exp [j(kx \sin \theta + kz \cos \theta)]$. (71)

A solution of this partial difference equation for \bar{F} which gives the proper values of all the field components is

$$\bar{F} = \bar{Z}_1(-j/k \sin \theta) \exp [j(kx \sin \theta + kz \cos \theta)] \\ = (-j\bar{Z}_1/k \sin \theta) \exp [j(k\rho \sin \theta \cos \phi + kz \cos \theta)]. \quad (72)$$

By well-known expansions in Bessel functions we have the relation

$$\exp [j(k\rho \sin \theta \cos \phi)] = \sum_{n=0}^{\infty} \epsilon_n(j)^n J_n(k\rho \sin \theta) \cos n\phi \quad (73)$$

where ϵ_n = Newman's number = 1 when $n=0$ and 2 for all other values of n .

We then obtain for the primary vector function

$$\bar{F}_{\text{pri}} = \bar{Z}_1(-j/k \sin \theta) \exp (jkz \cos \theta) \\ \cdot \sum_{n=0}^{\infty} \epsilon_n(j)^n J_n(k\rho \sin \theta) \cos n\phi. \quad (74)$$

This expression represents the sum of a number of standing cylindrical waves. The secondary-wave function must be of the same form excepting that it must represent diverging waves. Substituting the Hankel function in place of the Bessel function and putting in the unknown constants (a_n) we obtain for the secondary field:

$$\bar{F}_{\text{sec}} = \bar{Z}_1(-j/k \sin \theta) \exp (jkz \cos \theta) \\ \cdot \sum_{n=0}^{\infty} \epsilon_n(j)^n a_n U_n(k\rho \sin \theta) \cos n\phi. \quad (75)$$

Adding the two expressions we have for the total wave function:

$$\bar{F}_{\text{tot}} = \bar{Z}_1(-j/k \sin \theta) \exp (jkz \cos \theta) \\ \cdot \sum_{n=0}^{\infty} \epsilon_n(j)^n [J_n(k\rho \sin \theta) + a_n U_n(k\rho \sin \theta)] \cos n\phi. \quad (76)$$

To determine the amplitudes (a_n) of the secondary waves we make use of the boundary condition that the total electric force tangential to the surface of the cylinder must be zero, i.e., when $\rho=a$, \bar{E}_ϕ must be zero.

Then $\text{curl}_\phi \bar{F}_{\text{tot}} = 0$ when $\rho = a$ (77)

from which

$$a_n = \{-J_n'(ka \sin \theta) / U_n'(ka \sin \theta)\} \quad (78)$$

where the primes indicate derivatives with respect to the argument. The electric force \bar{E}_ϕ acting on the horizontal dipole with its axis circumferential and located at the position ($b, \phi, 0$) becomes

$$\bar{E}_{\phi \text{ tot}} = -\text{curl}_\phi \bar{F}_{\text{tot}} = -j \sum_{n=0}^{\infty} \epsilon_n(j)^n [J_n'(kb \sin \theta) \\ - \{J_n'(ka \sin \theta) / U_n'(ka \sin \theta)\} U_n'(kb \sin \theta)] \cos n\phi. \quad (79)$$

By the reciprocity law the horizontal electric force at a distant dipole due to a horizontal dipole located at the above-stated position near the cylinder is also given by the above expression. In (79) the first term in the brackets represents the primary field and the second term the secondary field. When the distance of the dipole from the axis of the cylinder is considerably greater than the radius of the cylinder the Bessel-Fourier series expression for the primary field converges much more slowly than the series for the secondary

field and under such conditions it may save labor to compute the primary field without the series expansion, separately compute the secondary field from the series, and then combine the two to obtain the total field.

In directions other than in the horizontal plane and one vertical plane a horizontal dipole radiates waves having a vertical component of electric force so that in addition to the field pattern for the horizontal component of electric field we must consider radiation patterns for the other component of electric force. In order to do this let us assume a distant electric dipole whose axis lies in the xz plane and is perpendicular to the ray for the origin. In the resulting electromagnetic wave the magnetic vector is entirely horizontal and is given by the expression

$$\bar{H}_y = \exp [j(kx \sin \theta + kz \cos \theta)]. \quad (80)$$

For reasons similar to those already explained the magnetic vector can be derived from a magnetic-vector potential in accordance with the relation

$$\bar{H}_y = \text{curl}_y \bar{A}_z = \bar{H}_\phi \cos \phi + \bar{H}_\rho \sin \phi. \quad (81)$$

Then

$$(-\delta \bar{A} / \delta x) = \exp [j(kx \sin \theta + kz \cos \theta)]. \quad (82)$$

The proper solution of this equation for our purposes is

$$\bar{A} = \bar{Z}_1(j/k \sin \theta) \exp [j(kx \sin \theta + kz \cos \theta)] \\ = \bar{Z}_1(j/k \sin \theta) \exp [j(k\rho \sin \theta \cos \phi + kz \cos \theta)]. \quad (83)$$

Expanding in the same manner as previously and assuming secondary waves with amplitudes b_n we obtain

$$\bar{A}_{\text{ntot}} = \bar{Z}_1(j/k \sin \theta) \exp (jkz \cos \theta) \\ \cdot \sum_{n=0}^{\infty} \epsilon_n(j)^n [J_n(k\rho \sin \theta) + b_n U_n(k\rho \sin \theta)] \cos n\phi. \quad (84)$$

Since

$$\bar{E} = (-j/k)(\text{grad div } \bar{A} + k^2 \bar{A}) \quad (85)$$

$$E_z = (-j/k) \{(\delta^2 \bar{A} / \delta z^2) + k^2 \bar{A}\} = -jk \sin^2 \theta \bar{A} \quad (86)$$

and

$$E_\phi = \frac{-j}{k} \left(\frac{1}{\rho} \frac{\delta^2 \bar{A}}{\delta \phi \delta z} \right) = (-j) \exp (jkz \cos \theta) \frac{\cos \theta}{\rho \sin \theta} \\ \cdot \sum_{n=0}^{\infty} \epsilon_n(j)^n \cdot n [J_n(k\rho \sin \theta) + b_n U_n(k\rho \sin \theta)] \sin n\phi. \quad (87)$$

Both tangential components E_ϕ and E_z of electric force must be zero when $\rho=a$, resulting in

$$b_n = -\{J_n(ka \sin \theta) / U_n(ka \sin \theta)\}. \quad (88)$$

The electric field along a horizontal dipole located at the position ($b, \phi, 0$) is then

$$E_\phi = -j2 \frac{\cos \theta}{kb \sin \theta} \sum_{n=1}^{\infty} (j)^n \cdot n [J_n(kb \sin \theta) \\ - \{J_n(ka \sin \theta) / U_n(ka \sin \theta)\} U_n(kb \sin \theta)] \sin n\phi. \quad (89)$$

From the recurrence formula for Bessel functions we may put (89) in the following form (90) which may be more convenient than (89) for some conditions:

$$E_\phi = -j \cos \theta \sum_{n=1}^{\infty} (j)^n [J_{n-1}(kb \sin \theta) + J_{n+1}(kb \sin \theta) \\ + \{J_n(ka \sin \theta) / U_n(ka \sin \theta)\} (U_{n-1}(ka \sin \theta) \\ + U_{n+1}(kb \sin \theta))] \sin n\phi. \quad (90)$$

Again, by the reciprocity principle, the electric field in the direction of the assumed dipole due to the dipole located in the specified position near the cylinder is also given by the last relation. To summarize, we have for the case of a horizontal dipole located near a vertical cylinder:

Horizontal electric force

$$E_{\phi} = j \sum_{n=0}^{\infty} \epsilon_n(j)^n [J_n'(kb \sin \theta) - \{J_n'(ka \sin \theta)/U_n'(ka \sin \theta)\} U_n'(kb \sin \theta)] \cos n\phi. \quad (91)$$

Vertically polarized electric force⁷

$$E_{\theta} = -j2 \frac{\cos \theta}{kb \sin \theta} \sum_{n=1}^{\infty} (j)^n \cdot n [J_n(kb \sin \theta) - \{J_n(ka \sin \theta)/U_n(ka \sin \theta)\} U_n(kb \sin \theta)] \sin n\phi. \quad (92)$$

B. Horizontal Dipole with Axis Radial

For this condition we may proceed in the same manner as that explained under *A*. The only difference is that we are now interested in the radial component of total electric force near the cylinder rather than in the circumferential. The radial component \bar{E}_{ρ} , due to the horizontally polarized wave represented by the vector function \bar{F}_z , is then

$$\bar{E}_{\rho} = -\text{curl}_{\rho} \bar{F}_z = -(1/\rho)(\delta \bar{F}/\delta \phi). \quad (93)$$

At the position of the near-by dipole ($\rho=b$, $\phi=\phi$, $z=0$) we obtain

$$E_{\rho} = -j \frac{2}{kb \sin \theta} \sum_{n=1}^{\infty} (j)^n \cdot (n) [J_n(kb \sin \theta) - \{J_n'(ka \sin \theta)/U_n'(ka \sin \theta)\} U_n(kb \sin \theta)] \sin n\phi. \quad (94)$$

Again, using the reciprocity principle this expression gives us the horizontal electric-field intensity of the horizontally polarized wave at a great distance from the dipole when the dipole is located at the position ($\rho=b$, $\phi=\phi$, $z=0$). The radial component of electric force for regions near the cylinder due to the wave having a purely horizontal \bar{H} vector derived from the vector function \bar{A} is given by

$$\begin{aligned} \bar{E}_{\rho} &= (-j/k) \text{grad}_{\rho} \text{div} \bar{A}_z = (-j/k)(\delta^2/\delta \rho \delta z) \bar{A}_z \\ &= (-j/k)(\delta/\delta \rho)(jk \cos \theta \bar{A}_z) = \cos \theta (\delta \bar{A}_z/\delta \rho) \end{aligned} \quad (95)$$

and

$$\begin{aligned} \bar{E}_{\rho} &= j \cos \theta \sum_{n=0}^{\infty} \epsilon_n(j)^n [J_n' kb \sin \theta] \\ &- \{J_n(ka \sin \theta)/U_n(ka \sin \theta)\} U_n'(kb \sin \theta) \cos n\phi \end{aligned} \quad (96)$$

when $\rho=b$, and $z=0$.

By reciprocity this expression also gives the electric vector of the wave from the cylinder and near-by dipole polarized in vertical planes.

Thus for the field from a horizontal dipole with axis pointed outwardly together with a vertical cylinder we have

⁷ To conserve words we shall define a vertically polarized wave as one whose magnetic force is entirely horizontal and "vertically polarized," electric force as the force belonging to a vertically polarized wave. Thus a vertically polarized electric force as defined here is not necessarily vertical.

(a) *Horizontally polarized wave component*

$$E_{\phi} = \frac{-j2}{kb \sin \theta} \sum_{n=1}^{\infty} (j)^n \cdot n [J_n(kb \sin \theta) - \{J_n'(ka \sin \theta)/U_n'(ka \sin \theta)\} U_n(kb \sin \theta)] \sin n\phi. \quad (97)$$

(b) *Vertically polarized wave component*

$$E_{\theta} = j \cos \theta \sum_{n=0}^{\infty} \epsilon_n(j)^n [J_n' kb \sin \theta - \{J_n(ka \sin \theta)/U_n(ka \sin \theta)\} U_n'(kb \sin \theta)] \cos n\phi. \quad (98)$$

C. Vertical Dipole and Cylinder

This condition is the simplest to analyze. As described under *A* we assume a dipole lying in a vertical plane at a great distance, thus resulting in a wave in which the magnetic field is purely horizontal. In this case we do not need the second assumption of a distant horizontal dipole since the wave from the latter can produce no electric force parallel to the direction of the axis of the cylinder and its near-by dipole. The vertical component of the electric force in the vicinity of the cylinder is then determined from (84), (86), and (88). By reciprocity this expression gives the total field E_{θ} along a distant dipole perpendicular to the ray. The result is

$$E_{\theta} = \sin \theta \sum_{n=0}^{\infty} \epsilon_n(j)^n [J_n(kb \sin \theta) - \{J_n(ka \sin \theta)/U_n(ka \sin \theta)\} U_n(kb \sin \theta)] \cos n\phi. \quad (99)$$

D. Dipoles Very Close to Cylinder

When the distance between the surface of the cylinder and the dipole is only a small fraction of a wavelength the two terms in the brackets representing the primary and secondary fields are nearly equal so that the formulas become nearly useless in the forms given. However, useful forms may be obtained by letting $b=a+\Delta a$, expanding the Bessel functions by Taylor's theorem, and neglecting higher-order terms. The process is straightforward and needs no discussion.

E. Dipole Arrays and Cylinders

All of the expressions for the field components which have been developed for the three orientations of a dipole near a cylinder may be expressed in the general form

$$E = \sum_{n=0}^{\infty} S_n(a, b, \theta, n) \begin{cases} \cos n\phi \\ \sin n\phi \end{cases} \quad (100)$$

where $S_n(a, b, \theta, n)$ is a function of a , b , θ , and n . When a second unit is placed in a position $\phi=\phi_0$ and fed so that its current leads that in the first by a phase angle ψ the field from the second unit becomes

$$E = \exp(j\psi) \sum_{n=0}^{\infty} S_n(a, b, \theta, n) \begin{cases} \cos n(\phi - \phi_0) \\ \sin n(\phi - \phi_0) \end{cases}. \quad (101)$$

If we have an array of m dipoles equally spaced by an angle $2\pi/m$, and the current in the P th dipole has a phase angle ψ_p the total field for the array is then

$$E = \sum_{p=1}^m \sum_{n=0}^{\infty} \exp(j\psi_p) S_n(a, b, \theta, n) \begin{cases} \cos [n\{\phi - 2\pi(P/m)\}] \\ \sin [n\{\phi - 2\pi(P/m)\}] \end{cases}. \quad (102)$$

For most of the arrays of practical interest this formula becomes considerably simpler upon expansion due to the cancellation of some of the terms. We shall not take the space to show the details of development of the expressions for the various arrays.

If an array consists of n tiers spaced apart by a distance S and fed with equal currents in phase and E_1 is the field from one tier the total field E_n becomes

$$E_n = E_1 \{ 1 + \exp(jkS \cos \theta) + \exp(j2kS \cos \theta) + \dots + \exp[j(n-1)kS \cos \theta] \} \quad (103)$$

$$= E_1 \frac{1 - \exp(jnkS \cos \theta)}{1 - \exp(jkS \cos \theta)} \\ = E_1 \exp\left(j \frac{n-1}{2} kS \cos \theta\right) \frac{\sin\{(n/2)kS \cos \theta\}}{\sin(kS/2 \cos \theta)} \quad (104)$$

and

$$|E_n| = E_1 \frac{\sin\{n(kS/2) \cos \theta\}}{\sin(kS/2 \cos \theta)} \quad (105)$$

the limit for $\theta = 90$ degrees being $E_n = nE_1$.

For a two-tier array this reduces to

$$E_2 = 2E_1 \cos\{(kS/2) \cos \theta\}. \quad (106)$$

F. Line Sources or Very High Stacks of Dipoles

It is of advantage in certain cases to know the behavior of waves from line rather than point sources. The viewpoint is somewhat similar to that taken in the treatment of ordinary radio-frequency transmission lines where the laws of propagation are strictly true only when the line section under consideration is part of a line of infinite length. There are many cases in practice where such an approximation is sufficiently

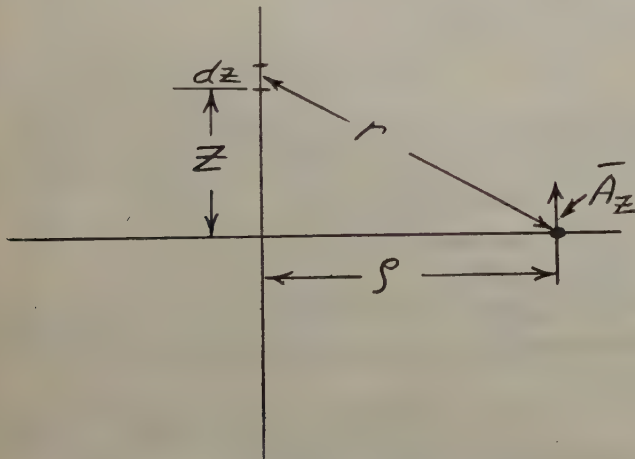


Fig. 30—Vector potential from line source.

accurate. By a line source for waves is meant a line of point sources all oscillating in phase. The elements of the line may be vertical electric doublets, horizontal electric doublets, or vertical magnetic doublets, the latter being equivalent to a stack of small horizontal loop antennas. Let us consider first a line source of vertical electric dipoles. Referring to Fig. 30 the current moment of an element dz is Idz and the retarded vector potential

$$d\bar{A}_z = (\bar{Z}_1 I / 4\pi C) \{ \exp(-jkr)/r \} dz \quad (107)$$

where

$$r^2 = \rho^2 + z^2.$$

The total vector potential \bar{A} at P is then

$$\bar{A} = \frac{\bar{Z}_1 I}{4\pi C} \int_{-\infty}^{+\infty} \exp\left(\frac{-jkr}{r}\right) dz. \quad (108)$$

Let us change the variable in the integral by letting $r = \rho \cosh \alpha$, then, since

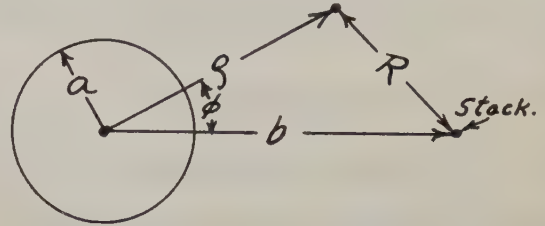


Fig. 31 Co-ordinates for cylinder and dipole stack.

$$\cosh^2 \alpha - \sinh^2 \alpha = 1, \quad z = \rho \sqrt{\cosh^2 \alpha - 1} = \rho \sinh \alpha,$$

and

$$dz = \rho \cosh \alpha d\alpha = r d\alpha$$

and the vector becomes

$$\bar{A} = \frac{\bar{Z}_1 I}{4\pi C} \int_{-\infty}^{+\infty} \exp(-jk\rho \cosh \alpha) d\alpha. \quad (109)$$

This is a standard form, for the Hankel function⁶ and therefore

$$\bar{A} = \bar{Z}_1 I \{ (-j)/4C \} U_0(k\rho). \quad (110)$$

The electric and magnetic forces may then be obtained by

$$\bar{H} = \text{curl } \bar{A}, \quad \bar{E} = (-j/k)(\text{grad div } \bar{A} + k^2 \bar{A}) \\ = -jk\bar{A} \text{ since } \text{div } \bar{A} \equiv 0. \quad (111)$$

Hence the diverging wave from a vertical line source of vertical electric dipoles may be represented by $U_0(k\rho)$, disregarding constants.

Now consider a vertical stack of horizontal dipoles, the axes of the dipoles lying in the direction of the y axis. The vector potential then becomes

$$\bar{A} = \bar{A}_y = \bar{y}_1 U_0(k\rho) = U_0(k\rho)(\rho_1 \sin \phi + \bar{\phi}_1 \cos \phi). \quad (112)$$

If the axes of a stack of horizontal dipoles are radial and lie along the x axis

$$\bar{A} = \bar{A}_x = \bar{x}_1 U_0(k\rho) = U_0(k\rho)(\rho_1 \cos \phi - \phi_1 \sin \phi). \quad (113)$$

For a vertical string of magnetic dipoles the electric vector potential is given by

$$\bar{F} = \bar{F}_z = \bar{Z}_1 U_0(k\rho). \quad (114)$$

G. Cylinder and Stack of Vertical Dipoles

If a high stack of dipoles rather than a single dipole is assumed near a cylinder it is not necessary to make use of the reciprocity theorem to avoid infinite integrals in the Fourier series for the waves. The advantage of using the direct method of approach is that we gain an exact knowledge of the fields in the near vicinity of the

⁶ Loc. cit., p. 218.

cylinder and the currents flowing along its surface as well as the radiation fields at great distances. In Fig. 31 assume a stack of vertical dipoles located at $\rho = b$, $\phi = 0$. The vector potential \bar{A}_ϵ at any position ρ, ϕ may be represented by

$$\bar{A}_z = \bar{Z}_1 U_0(kR), \quad (115)$$

where $R = \sqrt{\rho^2 + b^2 - 2\rho b \cos \phi}$. In order to satisfy boundary conditions we need to express the primary wave \bar{A} as a sum of cylindrical waves referred to axis of the cylinder. From the addition theorem for Bessel functions

$$U_0(kR) = \sum_{n=0}^{\infty} \epsilon_n U_n(kb) J_n(k\rho) \cos n\phi \text{ when } \rho < b \quad (116)$$

$$U_0(kR) = \sum_{n=0}^{\infty} \epsilon_n U_n(k\rho) J_n(kb) \cos n\phi \text{ when } \rho > b. \quad (117)$$

(It may be of interest to note that (116), and (117) prove the reciprocity theorem for this particular condition).

For the secondary waves we have a similar series with $U_n(K\rho)$ in place of $J_n(K\rho)$ to represent diverging waves. As under (E) we determine the unknown amplitudes from the law that the total electric force E_z along the surface of the cylinder must be zero and thus obtain for the total wave vector

$$A_z = \sum_{n=0}^{\infty} \epsilon_n [U_n(kb) J_n(k\rho) - U_n(kb) \{J_n(k\rho)/U_n(k\rho)\} U_n(k\rho)] \cos n\phi \quad (118)$$

when $\rho < b$

and

$$A_z = \sum_{n=0}^{\infty} \epsilon_n [J_n(kb) - \{J_n(ka)/U_n(ka)\} U_n(kb)] U_n(k\rho) \cos n\phi \quad (119)$$

when $\rho > b$

and

$$E_z = (-j/k)(\text{grad div } A_z + k^2 A_z) = -jk A_z. \quad (120)$$

For great distances (ρ) the asymptotic value of $U_n(k\rho)$ is

$$U_n(k\rho) \sim \sqrt{\frac{2}{\pi}} \frac{\exp\{-(jk\rho + \pi/4)\}}{\sqrt{k\rho}} \exp\left(jn \frac{\pi}{2}\right) \\ = \sqrt{\frac{2}{\pi}} j^n \frac{\exp\{-jk\rho + \pi/4\}}{\sqrt{k\rho}} \quad (121)$$

Thus for fixed large distances we obtain the same expression as that given under (E) for $\theta = 90$ degrees, i.e., the horizontal plane.

H. Stacks of Horizontal Dipoles Near Cylinder— Dipole Axes Circumferential

For this condition we proceed as before to start with but our vector potential is now

$$\bar{A}_y = \bar{A}_R + \bar{A}_\phi \quad (122)$$

$$A_R = U_0(kR) \sin \phi \quad (123)$$

and

$$A_\phi = U_0(kR) \cos \phi \quad (124)$$

from which

$$\bar{H} = \bar{H}_z = \text{curl } A_y = -k U_1(kR) \cos \phi \quad (125)$$

$$E_R = (-1/R)(\delta \bar{H}_z / \delta \phi) = k^2 \{U_1(kR)/k\rho\} \sin \phi \quad (126)$$

$$E_\phi = (-\delta H_z / \delta R) = k^2 U_1'(kR) \cos \phi. \quad (127)$$

Since the electric force has no vertical component the fields may be derived from a vector function \bar{F}_z . We then have

$$\bar{E} = -\text{curl } \bar{F}_z \quad (128)$$

$$\text{and } \bar{H} = (-j/k)(\text{grad div } F_z - k^2 F_z) = -jk \bar{F}_z. \quad (129)$$

Then

$$H_z = -k U_1(kR) \cos \phi = -jk \bar{F}_z \quad (130)$$

and

$$F_z = -j U_1(kR) \cos \phi = (-j/k) U_0'(kR) \cos \phi. \quad (131)$$

But

$$U_1(kR) \cos \phi = \sum_{m=-\infty}^{m=+\infty} U_{1+m}(kb) J_m(k\rho) \cos m\phi, \rho < b \quad (132)$$

$$= U_1 J_0 + (U_2 J_1 - U_0 J_1) \cos \phi \\ + (U_3 J_2 - U_1 J_2) \cos 2\phi + \dots$$

$$= -\sum_0^{\infty} \epsilon_n U_n'(kb) J_n(k\rho) \cos n\phi, \rho < b. \quad (133)$$

Hence

$$F = j \sum_0^{\infty} \epsilon_n U_n'(kb) J_n(k\rho) \cos n\phi, \rho < b. \quad (134)$$

Assume secondary

$$F_z = F_{z\text{sec}} = a_n U_n'(kb) U_n(k\rho) \cos n\phi. \quad (135)$$

Then the total electric force

$$E_{\phi(\text{tot})} = \text{curl } F_z = (\delta F_z / \delta \rho). \quad (136)$$

Hence when $\rho = a$

$$(\delta F_z / \delta \rho) = \text{zero and } a_n = \{J_n'(ka) / H_n'(ka)\} \quad (137)$$

and

$$E_\phi = jk \sum_0^{\infty} \epsilon_n [U_n'(kb) J_n'(k\rho) - \{J_n'(ka) / U_n'(ka)\} U_n'(kb) U_n'(k\rho)] \cos n\phi \quad (138)$$

when $\rho < b$

and

$$E_\phi = jk \sum_0^{\infty} \epsilon_n [J_n'(kb) - \{J_n'(ka) / U_n'(ka)\} U_n'(kb)] U_n'(k\rho) \cos n\phi \quad (139)$$

when $\rho > b$.

This becomes the same as the expression developed by the reciprocity theorem when we substitute the asymptotic expression for $U_n'(k\rho)$.

J. Stack of Horizontal Dipoles Near Cylinder— Dipole Axes Radial

The procedure for this condition is almost identical with that under (H) except that we start with a vector potential

$$\bar{A}_z = U_0(kR) \{\bar{\rho}_1 \cos \phi - \bar{\phi}_1 \sin \phi\}. \quad (140)$$

The result is

$$E_\phi = -jk \sum_0^{\infty} \epsilon_n [U_n'(kb) J_n'(k\rho) - \{J_n'(ka) / U_n'(ka)\} U_n'(kb) U_n'(k\rho)] \sin n\phi, \rho < b \quad (141)$$

$$E_\phi = -jk \sum_0^{\infty} \epsilon_n [J_n'(kb) - \{J_n'(ka) / U_n'(ka)\} U_n'(kb)] U_n'(k\rho) \sin n\phi, \rho > b \quad (142)$$

$$E_z = -k \sum_0^{\infty} \epsilon_n [U_n'(kb) J_n(k\rho) - \{J_n'(ka) / U_n'(ka)\} U_n'(kb) U_n(k\rho)] \sin n\phi, \rho < b. \quad (143)$$

K. Currents in Cylinder

Having developed the expressions giving the fields in the immediate vicinity of the cylinder from stacks of dipoles located near the cylinder we may immediately determine the current distribution in the surface of the cylinder from the law that the current density in the surface is equal to c times the magnetic field adjacent to the surface. For a stack of vertical electric dipoles we thus obtain for the current density on the cylinder

$$I = cH_\phi = c \operatorname{curl} \phi A_z = -c \sum_0^\infty \epsilon_n [U_n(kb)J_n'(ka) - U_n(kb)\{J_n(ka)/U_n(ka)\}U_n'(ka)] \cos n\phi. \quad (144)$$

For the stack of horizontal dipoles with circumferential axes the current flowing around the cylinder is

$$I = cH_z = -j\omega F_z = \omega \sum_0^\infty \epsilon_n [U_n'(kb)J_n(ka) - U_n'(kb)\{J_n'(ka)/U_n'(ka)\}U_n(ka)] \cos n\phi. \quad (145)$$

When the dipole axes of the stack are radial the current density is

$$I = -\omega \sum_0^\infty \epsilon_n [U_n'(kb)J_n(ka) - \{J_n'(ka)/U_n'(ka)\}U_n'(kb)U_n(ka)] \sin n\phi. \quad (146)$$

The distribution of current in the cylindrical surface for a dipole stack should be approximately the same as that for a single dipole at least in the plane containing the dipole.

L. Horizontal Dipole and Dielectric Cylinder

By a process similar to that used for a perfectly conducting cylinder we may develop expressions for the radiation pattern from a dipole or arrays of dipoles near a dielectric cylinder. When such a cylinder is assumed we must consider three wave components, the primary wave, the external or reflected secondary waves, and the internal or refracted secondary waves. In the boundary between air and the dielectric cylinder the following conditions must hold. The tangential components of both total electric and total magnetic force must be

continuous in crossing the boundary. Also the total radial components of magnetic induction and electric displacement must be continuous. We shall not take up the space required to show the procedure. It results in the following expression for the magnetic field H_z of the secondary wave

$$H_{z\text{sec}} = \sum_{n=0}^\infty \epsilon_n J_n a_n U_n(k\rho) \cos n\phi \quad (147)$$

where

$$a_n = -\frac{J_n(ka)J_n'(k_2a) - \eta J_n'(ka)J_n(k_2a)}{U_n(ka)J_n'(k_2a) - \eta U_n'(ka)J_n(k_2a)}, \quad (148)$$

in which if ϵ_2 is the dielectric constant of the cylinder

$$\eta = \sqrt{\epsilon_2} = \text{refraction coefficient} \quad (149)$$

$$k_2 = \eta k = \sqrt{\epsilon_2} k = \sqrt{\epsilon_2} x(2\pi/\lambda) \\ = \text{propagation constant in cylinder.} \quad (150)$$

The cylinder need not be a pure dielectric. If its conductivity is σ (in Heaviside-Lorentz units) we may use a complex dielectric constant $\epsilon_2 = \epsilon_0 - j\sigma/\omega$. However, the arguments of the Bessel functions then become complex and the values of the functions are difficult to evaluate⁸ except when the ratio of conductivity to frequency is either quite large or quite small compared to ϵ_0 . Similar formulas may be developed in the same way for a vertical dipole in dielectric cylinder but we shall not write them.

Additional References

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* This excellent treatise was published after writing this report. Chapter VI, "Cylindrical Waves," gives a detailed treatment of cylindrical-wave functions.

⁸ Works Project Administration tables are in the process of computation. Certain of these tables are obtainable from the National Bureau of Standards, Washington, D. C.; others are to be published by the Columbia University Press, New York, N. Y.

The Radiation Field of a Symmetrical Center-Driven Antenna of Finite Cross Section*

CHARLES W. HARRISON, JR.†, ASSOCIATE I.R.E. AND RONOLD KING†, ASSOCIATE I.R.E.

Summary—A simple method is advanced for calculating the distant field of a symmetrical center-driven antenna of known effective cross section. This is accomplished by introducing two fictitious antennas carrying currents of simple analytical form and of such amplitude and phase as to approximate closely the actual distribution of current. In the case of thick antennas, this departs significantly from the sinusoidal distribution ordinarily assumed. It is demonstrated that for antennas of moderate thickness the

shape of the vertical field pattern differs only very slightly from that for an indefinitely thin antenna carrying a simple sinusoidal current. The magnitude of the field of the actual antenna differs by only a few per cent from that of the indefinitely thin antenna if the maximum value of the square root of the sum of the squares of the quadrature components of the current in the former is made equal to the maximum sinusoidal current in the latter. The phase of the field for the actual antenna differs from that of the indefinitely thin antenna. The cross section of a cylindrical antenna in which the magnitude of the current approximates the measured distribution of current along on an actual antenna is defined to be the effective cross section of the actual antenna.

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† Cruft Laboratory and Research Laboratory of Physics, Harvard University, Cambridge, Massachusetts.

INTRODUCTION

IN a recent paper the writers have discussed the distribution of current in a symmetrical center-driven antenna of nonvanishing radius.¹ One of the conclusions reached was that the distribution of current in an antenna of appreciable thickness differs considerably from a simple sine curve. Accordingly, it is to be expected that the distant field of an actual antenna will differ from that computed for an indefinitely thin antenna of the same length carrying a sinusoidally distributed current. This is also suggested by the work of L. V. King.²

Rather intricate equations (originally due to Hallén)³ were derived¹ for calculating the correct distribution of current for cylindrical antennas. It is possible, by an exceedingly tedious procedure, to determine by direct integration the distant field using this correct formula for the current. A simpler method, which is certainly adequate for all practical purposes, is to approximate each of the quadrature components of current in the antenna by a fictitious antenna carrying a current of simple analytical form which is a satisfactory equivalent of the actual distribution. Then by properly combining the fields calculated for each of these fictitious antennas in the distant zone, the radiation field of the actual antenna may be ascertained to a good approximation at least for cylindrical antennas of known radius.

A correct and also practical method for calculating the electric field of an antenna with a nonsinusoidally distributed current—and strictly this means all antennas which are not extremely thin—is to determine the field due to each quadrature component of the current, and then combine these into a resultant by taking the square root of the sum of the squares. Only if the phase angle of the current can be shown to be constant *along the entire length of the antenna* (as it can approximately, for example, for cylindrical antennas with half-lengths near a quarter wavelength) is it correct to assume that the phase is independent of the distance along the axis of the antenna. In such cases it is legitimate to use the square root of the sum of the squares of the quadrature components of the current as the current-distribution function.

The experimental determination of the distribution of current along an antenna is difficult because it is usually not possible to determine separately the quadrature components. A small wavemeter moved along parallel and quite close to the antenna, as described, for example, by Gihring and Brown,⁴ measures

the magnitude of the quadrature components to a satisfactory approximation, but does not permit determining the phase angle of the currents as was pointed out in general terms by L. V. King.⁵ Since in most cases this angle varies with distance along the antenna, it is obviously quite incorrect to assume that if the magnitude of the current is known, one may simply ignore the phase angle or assume that it reverses if the magnitude becomes small and then large. This is, for example, what was done by Gihring and Brown in calculating both the electric field and the radiation resistance of antennas with nonsinusoidally distributed currents. These investigators also recognized and pointed out the limitations of this procedure. Actually the magnitude of the current along any antenna of finite thickness can never reach zero except at the end of the antenna, and neither the phase nor the direction of the current can be determined using a wavemeter which reads current on a thermal milliammeter.

The present approach to the problem of determining accurately the distant field of symmetrical center-driven antennas (or of vertical base-driven antennas over a highly conducting plane) of unknown effective cross section is, first, to plot the observed distribution of current as measured, for example, using a wavemeter; and second, by a judicious application of the formulas for the current distribution in moderately thick cylindrical antennas, to obtain curves for the square root of the sum of the squares of the quadrature components of the current in antennas of several different radii. Then by a curve-fitting process, an estimate of the effective antenna cross section is made in terms of an approximate equivalent circular cross section (whether the actual cross section be triangular, square, etc.). In this way one has achieved the desired end, namely, that of obtaining satisfactory approximations for the quadrature components of the current in the actual antenna.

The analysis for the symmetrical center-driven antenna may be applied rigorously to an antenna over a perfectly conducting earth, and the fields obtained in this paper apply exactly to this case. In practice, when the earth is not perfectly conducting, radial currents flowing along the surface of the earth also have quadrature components which affect the distant field. The present analysis includes the effect on the field pattern of quadrature currents in the antenna, but does not take into account the effect of such currents in an earth of finite conductivity. The effect of these latter on the distant field of short antennas, or of sufficiently thin antennas for which a sinusoidal distribution of current is a satisfactory approximation, has been determined by Strutt.⁶ In the case of a thick

¹ Ronold King and Charles W. Harrison, Jr. "The distribution of current along a symmetrical center-driven antenna," *Proc. I.R.E.*, vol. 31, pp. 548-567; October, 1943.

² L. V. King, "On the radiation field of a perfectly conducting base insulated cylindrical antenna over a perfectly conducting plane earth, and the calculation of radiation resistance and reactance," *Phil Trans. Royal Soc. (London)*, vol. 236, pp. 394-422; November 2, 1937.

³ E. Hallén, "Theoretical investigations into the transmitting and receiving qualities of antennas," *Nava Acta Upsalienses*, ser. 4, vol. 11, no. 4, pp. 3-44; 1938.

⁴ H. E. Gihring and G. H. Brown, "General considerations of tower antennas for broadcast use," *Proc. I.R.E.*, vol. 23, pp. 311-356; April, 1935.

⁵ See page 382 of footnote reference 2.

⁶ M. J. O. Strutt, "Strahlung von Antennen unter dem Einfluss der Erdbodeneigenschaften," *Annal. der Phys.*, vol. 1, pp. 721-772; 1929.

antenna above an imperfect earth both effects must be superimposed.

THE DISTANT FIELD DUE TO SIMPLE DISTRIBUTIONS OF CURRENT

The distant electric field of a symmetrical center-driven antenna may be calculated conveniently by use of the formula

$$E_{\theta r} = \frac{j\omega\Pi}{4\pi} \frac{e^{-j\beta R_0}}{R_0} \int I_{z'} e^{j\beta z' \cos \theta} \sin \theta dz'. \quad (1)$$

Here the integration is to be carried out over the length of the antenna. The following notation is used.

$E_{\theta r}$ is the electric field in the distant or radiation zone of the antenna in volts per meter

ω is 2π multiplied by the frequency

Π is the magnetic constant of space given numerically by $\Pi = 4\pi \times 10^{-7}$ henry per meter

β is the propagation constant in radians per meter, and equals $2\pi/\lambda$ where λ is the wavelength

R_0 is the distance from the point of field calculation in the distant zone to a convenient reference origin 0 at the center of a center-driven antenna or at the base of a vertical base-driven antenna over a perfectly conducting half-space

$I_{z'}$ is the complex current amplitude in amperes flowing in the element dz'

z' is the distance from the reference origin at the center of the antenna to the element dz'

R_0 , θ , and ϕ form a set of spherical co-ordinates with origin at 0. ϕ does not appear in (1) because rotational symmetry obtains

Assuming a current distribution of the form

$$I_{z'} = I_m \sin \beta(h - |z'|) \quad (2)$$

and using (1), one obtains

$$E_{\theta r} = j60I_m \frac{e^{-j\beta R_0}}{R_0} \left[\frac{\cos(H \cos \theta) - \cos H}{\sin \theta} \right]. \quad (3)$$

This is the well-known relation for the distant field of an antenna of half-length h , ($H = \beta h$), referred to the maximum current.

If the current is of the form

$$I_{z'} = I_0 \left[\frac{\cos \beta z - \cos H}{1 - \cos H} \right], \quad (4)$$

one obtains

$$E_{\theta r} = j60I_0 \frac{e^{-j\beta R_0}}{R_0} \left[\frac{1}{(1 - \cos H) \sin \theta} \left(\sin H \cos(H \cos \theta) - \frac{\cos H \sin(H \cos \theta)}{\cos \theta} \right) \right]. \quad (5)$$

The equation for a triangular current distribution is

$$I_{z'} = \frac{I_0(h - z)}{h}. \quad (6)$$

Using (6) in conjunction with (1) gives

$$E_{\theta r} = j60I_0 \frac{e^{-j\beta R_0}}{R_0} \frac{\sin \theta}{H \cos^2 \theta} [1 - \cos(H \cos \theta)]. \quad (7)$$

If one assumes a uniform current distribution, i.e., one that is independent of z' ,

$$I_{z'} = I_0 \quad (8)$$

then

$$E_{\theta r} = j60I_0 \frac{e^{-j\beta R_0}}{R_0} H \sin \theta. \quad (9)$$

THE DISTANT FIELD OF A MODERATELY THICK ANTENNA

An inspection of the curves for the current distribution in antennas of nonvanishing cross-section⁷ reveals the very interesting fact that in all cases the quadrature components of current may be roughly approximated by the distributions given by (2) and (4) as shown in equation (70) of reference 1. This may be written in the following equivalent form.

$$I_z = I_z'' + jI_z' = I_0'' \left[\frac{\cos \beta z - \cos H}{1 - \cos H} \right] + jI_m' \sin(H - \beta|z|). \quad (10)$$

The expression for the distant field due to this distribution is obtained using (2) and (4) in (1). It is

$$E_{\theta r} \approx j60I_m' \frac{e^{-j\beta R_0}}{R_0} \left[\frac{\cos(H \cos \theta) - \cos H}{\sin \theta} + \frac{jC}{(1 - \cos H) \sin \theta} \left(\sin H \cos(H \cos \theta) - \frac{\cos H \sin(H \cos \theta)}{\cos \theta} \right) \right]. \quad (11)$$

It has been convenient to introduce the amplitude ratio for the quadrature components in the form $C = I_0''/I_m'$. I_0'' is the component of current in phase with the driving voltage at the center of the antenna; I_m' is the maximum value of the sinusoidally distributed component of current in quadrature with the driving voltage.

For the special case, $H = \pi$ or $h = \lambda/2$ (11) becomes

$$E_{\theta r} \approx j60I_m' \frac{e^{-j\beta R_0}}{R_0} \left[\frac{\cos(\pi \cos \theta) + 1}{\sin \theta} + \frac{jC}{2 \sin \theta} \frac{\sin(\pi \cos \theta)}{\cos \theta} \right]. \quad (12)$$

In this case an alternative representation, using the distribution,

$$I_z = I_0'' [1 - z/h] + jI_m' \sin(H - \beta|z|) \quad (13)$$

gives an equally satisfactory approximation. With (2) and (6) used in (1) one obtains

$$E_{\theta r} \approx j60I_m' \frac{e^{-j\beta R_0}}{R_0} \left[\frac{\cos(\pi \cos \theta) + 1}{\sin \theta} + \frac{jC \sin \theta}{\pi \cos^2 \theta} [1 - \cos(\pi \cos \theta)] \right]. \quad (14)$$

Curves for the distant field have been computed using (11) for several antennas of different length but

⁷ Figs. 19 and 20 of footnote reference 1.

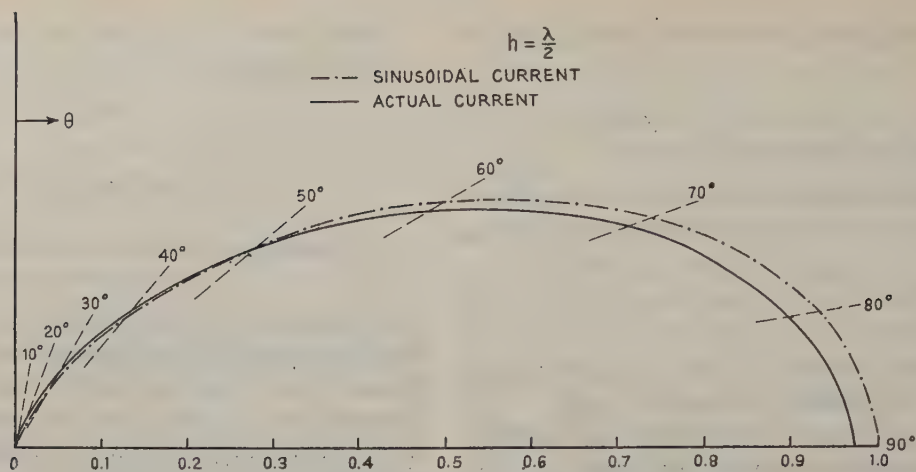


Fig. 1—Vertical field patterns of an isolated center-driven antenna of radius a and half-length $h = \lambda/2$ or of a base-driven antenna of length $h = \lambda/2$ erected vertically over a perfectly conducting plane. The curve marked "sinusoidal current" is for an indefinitely thin antenna for which $a = 0$; the curve marked "actual current" is computed for an antenna for which $h/a = 75$.

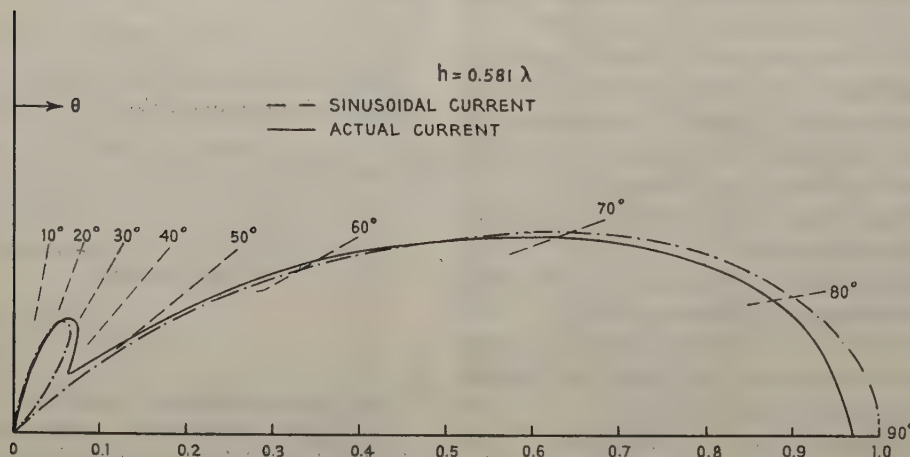


Fig. 2—Like Fig. 1 but with $h = 0.581 \lambda$, $h/a = 45$.

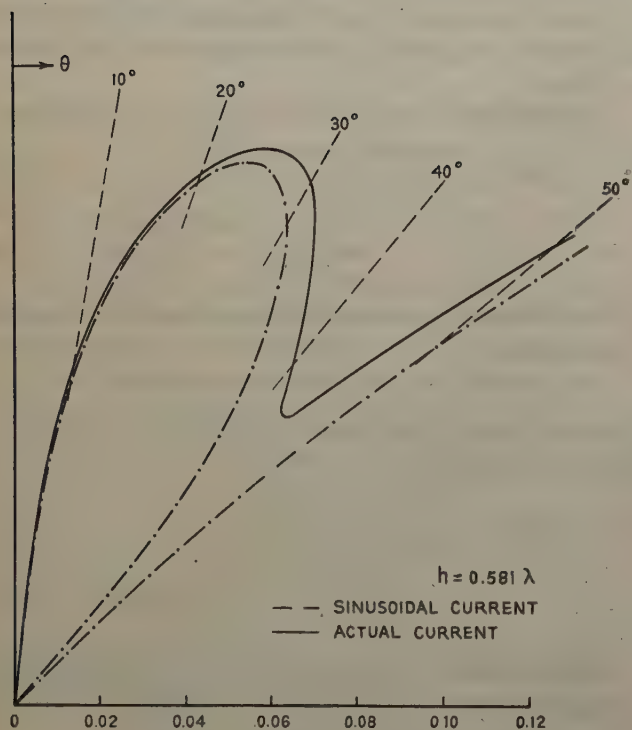


Fig. 3—An enlarged section of Fig. 2.

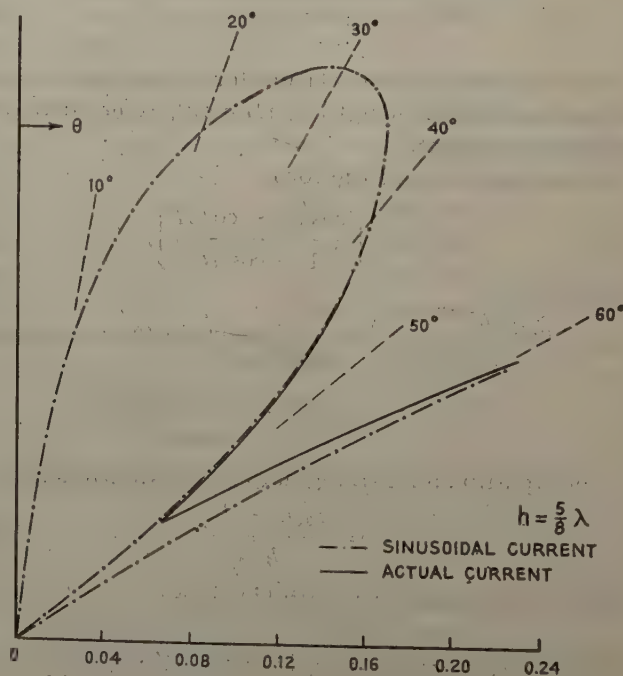


Fig. 4—A section like Fig. 3 but for $h = 5/8 \lambda$; $h/a = 75$.

all of the same thickness ($\Omega = 2 \ln(2h/a) = 10$), with the exception of that for which $h = 0.581\lambda$. For this case $\Omega = 9$. In all cases the maximum value along the antenna of $\sqrt{(I_x')^2 + (I_x'')^2}$ was set equal to I_{\max} in a simple sinusoidal distribution.

It is clear from the curves shown in Figs. 1 to 6 that the field patterns of the thick antenna differ only slightly from those of the infinitely thin antenna. They are somewhat rounded off where the fields of the simple sine-wave antenna pass through zero. However, this effect is quite small for antennas even as thick as implied by $\Omega = 10$. It is less for antennas of smaller effective cross section. In magnitude the fields calculated for the actual and the sinusoidal distributions differ by only a few per cent. In phase they are, of course, entirely different.

Figs. 2 and 3 show the distant field computed from (11) for an antenna with $h = 0.581\lambda$ or $H = 3.64$ using

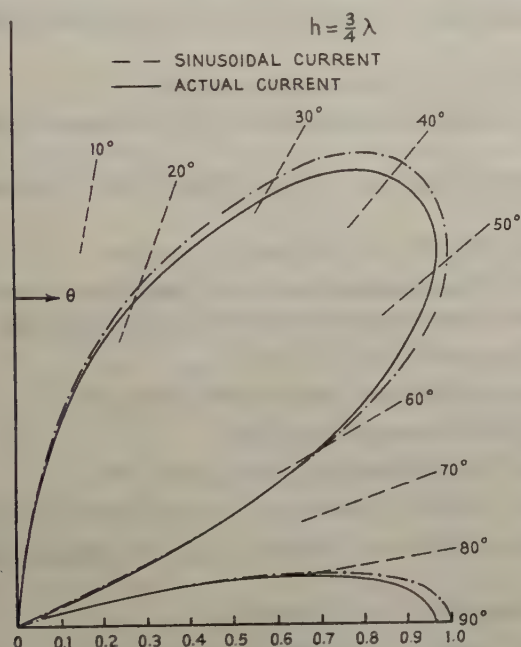


Fig. 5—Like Fig. 1 but with $h = 3\lambda/4$.

the distribution of current computed for this length and for $\Omega = 9$ by L. V. King.² The data are given in his Fig. 4 on page 393. The ratio factor C was determined in this case using his figure. A comparison of Figs. 2 and 3 with the distant field computed by L. V. King²

(using of course this same distribution of current), as given in his Figs. 6 and 7 on pages 398 and 399, shows appreciable difference. The very considerable increase in the minor lobe with increasing thickness as obtained by L. V. King is not verified. Since both components

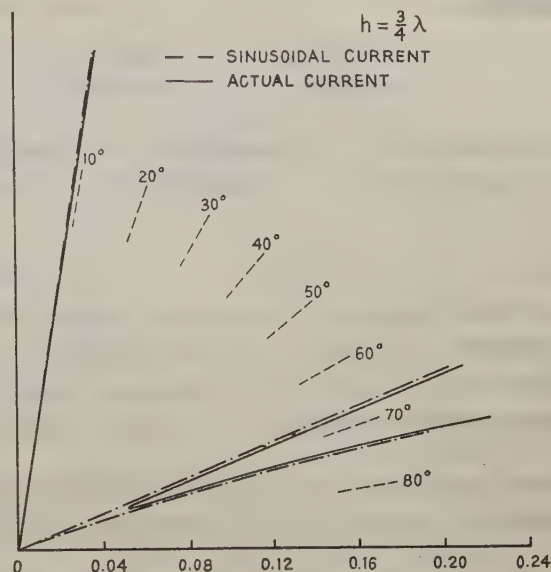


Fig. 6—An enlarged section of Fig. 5.

of the current are very well represented by (10) with a correctly adjusted factor C , it is difficult to see how the present simple and straightforward procedure (once the distribution of current is given) can be much in error. Consequently, the writers do not believe that minor lobes in the field pattern of moderately thick antennas are significantly different from those of extremely thin antennas of the same length except where the latter have sharp zeros.

CONCLUSION

The results of the present analysis indicate that for purposes of computing the shape of the pattern of the distant field even for relatively thick antennas a simple sinusoidal distribution is entirely adequate if it is understood that sharp zeros are rounded off. For more accurate determinations of the distant field including both its magnitude and phase the method described above may be used with only a small increase in complexity.

Corrections

The following typographical changes should be made in "The Distribution of Current Along a Symmetrical Center-Driven Antenna," by Ronold King and Charles W. Harrison, Jr., *PROC. I.R.E.*, vol. 31, pp. 548-567; October, 1943.

page 549, column 2, line 16 from bottom: change \cdot to \circ , and T to t
 line 8 from bottom: change interval to internal
 page 550, column 1, equation (12b) change subscript r to p on A

page 551, column 1, line after equation (24): change (15) to (22)
 line 2 after equation (24): change (13) to (15)
 page 551, column 2, equation (36): change $-$ to $+$ before $1/\Omega$
 page 552, column 2, line 14 after equation (50): change length to half-length
 page 565, column 2, equation (83): change $-$ to $+$ before $\frac{1}{2}$
 page 566, column 1, equation (84): change $-$ to $+$ before $\frac{1}{2}$
 equation (86): move first brace to between $-$ and F_0
 equation (91): change $-$ to $+$ after F_0

THE INSTITUTE OF RADIO ENGINEERS

INCORPORATED



SECTION MEETINGS

ATLANTA
December 17

CHICAGO
December 17

CLEVELAND
December 23

DETROIT
December 21

LOS ANGELES
December 21

NEW YORK
January 5

PHILADELPHIA
January 6

PITTSBURGH
January 3

WASHINGTON
January 3

SECTIONS

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BUENOS AIRES—Chairman, G. J. Andrews; Secretary, W. Klappenbach, *La Nacion*, Florida 347, Buenos Aires, Argentina.

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WASHINGTON—Chairman, C. M. Hunt; Secretary, H. A. Burroughs, Rm. 7207, Federal Communications Commission, Washington, D. C.

Institute News and Radio Notes

Board of Directors

At the regular meeting of the Board of Directors, which took place on October 6, 1943, the following were present: L. P. Wheeler, president; S. L. Bailey, E. F. Carter, W. L. Everitt, H. T. Friis, Alfred N. Goldsmith, editor; G. E. Gustafson, O. B. Hanson, R. A. Heising, treasurer; F. B. Llewellyn, Haraden Pratt, secretary; G. T. Royden (guest), F. E. Terman, B. J. Thompson, H. M. Turner, H. A. Wheeler, W. C. White, and W. B. Cowilich, assistant secretary.

The actions of the Executive Committee taken at its meeting on September 7, 1943, were ratified.

President Wheeler reported that the Executive Committee had approved 114 applications for Associate grade and 90 for Student grade.

The recommended changes to be made as the result of the adopted Constitutional amendments, which were given in the joint report from Chairmen G. T. Royden and B. J. Thompson of the Admissions and Membership Committees, respectively, were discussed at length. The actions taken included the decision to mail the proposed Bylaws amendments to the Board members, as prescribed by the Constitution; to transfer nearly all those of present Member status to the new Senior Member grade, and all Juniors to the Associate grade; to use dark blue as the emblem color for the Senior Member grade and light blue as that for the new Member grade; to incorporate the recommended changes in the general membership-application blank and to make appropriate changes in other printed material of the Institute; and, to have the Membership Committee take steps to notify present Associates concerning transfer to the new Member grade.

Secretary Pratt recorted on the recent meetings of the Radio Technical Planning Board which he attended as the Institute representative, and stated that Dr. W. R. G. Baker had been elected RTPB Chairman. A vote was taken on two proposed changes in the "RTPB—Organization and Procedure."

The Institute Committee on the RTPB consisting of Chairman Pratt, also the representative; B. J. Thompson, also the alternate; H. M. Turner, and Editor Goldsmith, was unanimously reappointed.

Treasurer Heising, as chairman of the Investment Committee, gave a report on matters pertaining to the Institute investments, which were discussed at length. The actions taken included the approval of arrangements for amending the Institute charter, and of the following bank resolution:

"Resolved: That any two of the following: viz., the President, the Secretary, the Treasurer and the Editor, be and they hereby are expressly authorized at all times to make and execute, in name of The Institute of Radio Engineers, Inc., any and all necessary powers of attorney, acts of assignment

and/or instruments of transfer, for the sale, assignment and transfer of any and all bonds standing in the name of The Institute of Radio Engineers, Inc."

President Wheeler stated that, as a result of the joint report submitted by F. B. Llewellyn and H. A. Wheeler, the Executive Committee had taken steps toward increasing the distribution of technical information and the activities of the technical committees.

The subject of professional representation of radio engineers was introduced and provision was made for appointing a committee to study the subject.

Editor Goldsmith reviewed several editorial matters, including the papers available for the PROCEEDINGS, the preparation of a special presentation for the membership and the industry on certain postwar matters, and the status of the paper-supply situation for 1943 and 1944.

H. P. Westman was appointed alternate representative on the ASA Sectional Committee on Standards for Drawings and Drafting Room Practices, and Martin Matheson and Frank L. Egner to the Papers Procurement Committee.

It was announced by President Wheeler that Dr. B. E. Shackelford had accepted the chairmanship of the arrangements committee on the Winter Technical Meeting, to take place in New York City during January, 1944.

Consideration was given to a letter from Professor E. H. Armstrong.

President Wheeler called attention to recent correspondence from The Royal Electrical and Mechanical Engineers, a new British society which was recently formed.

The Institute Representatives in Colleges, listed on page 589 of the October, 1943, issue of the PROCEEDINGS, were appointed for the term ending June, 1944, with the changes indicated below:

University of Illinois: A. J. Ebel

Oregon State College: A. L. Albert

Executive Committee

The Executive Committee meeting, held on October 5, 1943, was attended by L. P. Wheeler, president; Alfred N. Goldsmith, editor; R. A. Heising, treasurer; F. B. Llewellyn, Haraden Pratt, secretary; H. A. Wheeler, and W. B. Cowilich, assistant secretary.

Approval was granted to 114 applications for admission to Associate grade and 90 to Student grade.

Assistant Secretary Cowilich reported on several office matters including the overtime work of the staff during September, and stated that the winter working schedule, calling for longer hours, became effective in October.

The need for larger office quarters was given further consideration.

Matters pertaining to the Buenos Aires and New York Sections were discussed.

The recommendation was made to the

Board of Directors that Martin Matheson and Frank L. Egner be appointed to the Papers Procurement Committee.

Editor Goldsmith explained that the restricted paper allotment, granted by the War Production Department, necessitate sharply limiting forthcoming issues of the PROCEEDINGS with respect to number of pages and copies printed and that, despite the severe paper economies put into practice, the situation must be regarded as difficult. It was also indicated that steps are being taken to prepare an appeal to the WPB relative to the paper needed for printing the PROCEEDINGS in 1944.

Among the other editorial matters, reported by Editor Goldsmith, it was noted that the quantity and quality of papers on hand are of satisfactory order, and that a special article on certain postwar matters might soon be made available to the membership and the industry.

Announcement was made of the availability of reprint copies of the "Standards on Electronics, 1938," in the new format. It was decided to reprint immediately a limited number of copies of the "Standards on Electroacoustics, 1938," also to be in the new format.

The appointment of H. P. Westman, as alternate Institute representative on the ASA Sectional Committee on Standards for Drawings and Drafting Room Practices, was recommended to the Board of Directors.

President Wheeler called attention to the acceptance of Dr. B. E. Shackelford for the chairmanship of the committee on arrangements for the Institute's Winter Technical Meeting, which will be held in New York City during January, 1944.

The report on expanding the technical-committee and related activities, prepared jointly by F. B. Llewellyn and H. A. Wheeler was discussed and followed by certain actions.

Matters pertaining to Institute investments were given consideration.

A recent letter from the American Television Society, on postwar problems of television, was read and discussed.

The recommended changes in Bylaws, membership-application blank, emblem colors, and related matters, necessitated by the adopted Constitutional amendments and contained in the joint report of Chairmen G. T. Royden and B. J. Thompson of the Admissions and Membership Committees, respectively, were considered and referred to the Board of Directors.

President Wheeler called attention to the arrival of petitions for the formation of Institute Sections at Dayton, Ohio, and San Diego, California.

It was decided to refer the requests for permission to form student branches at Northwestern Technological Institute and Drexel Institute of Technology, to the Institute Representatives at those colleges.

The appointment of A. J. Ebel, as Institute Representative at the University of Illinois, was recommended to the Board of Directors.

Contributors



PHILIP S. CARTER

Philip S. Carter (A'29-M'38) was born in 1896 at Glastonbury, Connecticut. He received the A.B. degree in mechanical engineering from Stanford University in 1918 and later during that year he was with the Signal Corps of the U. S. Army. During 1919-1920, Mr. Carter was with the General Electric Company; since 1920 he has been with R.C.A. Communications, Inc., and RCA Laboratories. In 1940 he received the Modern Pioneer Award from the National Association of Manufacturers. He is a Member of the American Mathematical Society and Sigma Xi.

RCA Manufacturing Company during 1935-1937; and with Agfa Ansco from 1938 to 1942. Since 1942, Mr. Coroniti has been at the Radiation Laboratory of the Massachusetts Institute of Technology.



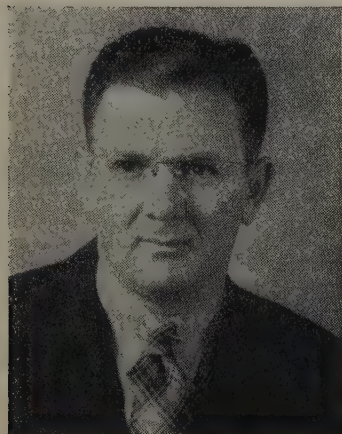
C. A. HULTBERG

C. A. Hultberg (M'34) was born in Chicago, Illinois, on March 4, 1904. He received the B.E.E. degree from the University of Detroit in 1928. During 1924 and 1925, while attending the university, he was in charge of radio interference-elimination work for the City of Detroit, Department of Street Railways. He was a design engineer with Universal Wireless Communications Company during 1929 and 1930 and the following three years were spent with the Stewart Warner Alomite Corporation as a radio development engineer. From August, 1933, to October, 1934, he was engaged by Hygrade Sylvania Corporation on research and circuit analysis. During 1934-1935, he acted as chief engineer of L' Tatro Products Corporation. In 1936, he joined the engineering department of Crosley Radio Corporation, as a receiver development engineer, for a period of two years. In 1938, he was engaged by Dominion Electrohome Industries, Ltd., of Canada as chief engineer. Early in 1942 Mr. Hultberg was appointed engineering consultant and director of design of Dominion Electrohome Industries Ltd., and of the Radio Production Alliance, with joint laboratories in Kitchener, Ontario, Canada. He is also registered with the Association of Professional Engineers, of the Province of Ontario.



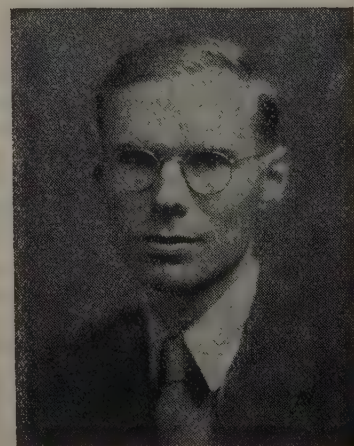
MIKHAIL S. NEIMAN

Mikhail S. Neiman (M'42) is a native of Sevastopol, U.S.S.R. He was graduated from the Politechnical Institute of Leningrad in 1928 and received the D.Sc. degree from the Electrotechnical Institute of Leningrad in 1939. From 1928 to 1935 he was a research engineer in the Leningrad Radio Research Institute of Glavradioprom (Central Radio Industry) and in charge of its laboratory from 1935 to 1941. Dr. Neiman became a professor at the Electrotechnical Institute of Leningrad in 1939. Since 1941 he has been in charge of the radio division of the communication department of the Government Purchasing Commission of the U.S.S.R. in the United States.



SAMUEL S. CORONITI

Samuel S. Coroniti (A '31) was born in Keiser, Pennsylvania, in 1908. He received the B.S. degree in engineering physics from Lehigh University in 1931 and the M.S. degree in physics from the University of Michigan in 1933. He was in the X-ray division of the Westinghouse Lamp Company in 1931; with the General Electric Company and



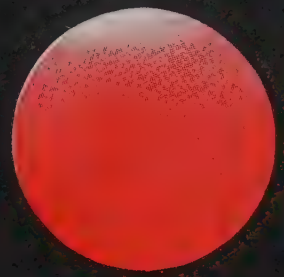
J. R. PIERCE

J. R. Pierce (S'35-A'38) was born at Des Moines, Iowa, on March 27, 1910. He received the B.S. degree in 1933 and the Ph.D. degree in 1936 from the California Institute of Technology. In 1936 Dr. Pierce became a member of the Technical Staff of the Bell Telephone Laboratories, where he is engaged in electronics research.

For a biographical sketch of C. W. Harrison, Jr., and Ronold King, see the PROCEEDINGS for October, 1943.

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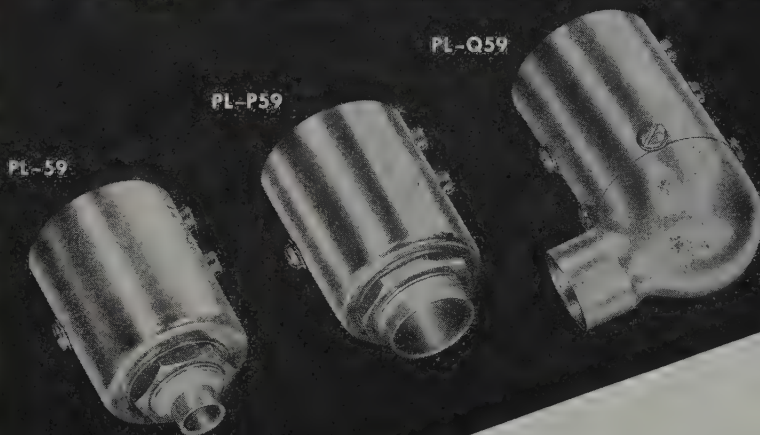
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56 64	104	124	354		61	76	61	76	61	76
58 65	108	125			62	77	62	77	62	77
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Section Meetings

BOSTON

"Evaluation of Plastics," by W. A. Zinzow, Bakelite Corporation; May 7, 1943.
An Address by Dr. L. P. Wheeler, President of The Institute of Radio Engineers; May 7, 1943.

CHICAGO

"Transmission Lines and Wave Guides," by Dr. C. S. Roys, Illinois Institute of Technology; May 21, 1943.
"Directional and Nondirectional Systems," by Dr. R. J. Moon, University of Chicago; May 21, 1943.
"Coupling and Phasing Devices," by Dr. V. J. Andrew, Victor J. Andrew Company; May 21, 1943.

CINCINNATI

"The Electron Microscope," by Professor A. F. Prebus, Ohio State University; April 20, 1943.

KANSAS CITY

"A Low-Frequency Exponential Horn of Small Dimensions," by R. N. White, Transcontinental and Western Air, Inc.; January 28, 1943.
"Piezoelectric Applications," by Ashly Elbl, Crystal Products Company; May 13, 1943.
"The De Rosa System of Artificially Produced Wide-Range Audio," by H. K. Morgan, Transcontinental and Western Air, Inc.; May 13, 1943.

LOS ANGELES

"A Wide-Band Cathode-Ray Oscilloscope," by Dr. E. D. Cook (Presented by P. G. Caldwell), General Electric Company; April 20, 1943.
"Practical Applications of the Wide-Band Cathode-Ray Oscilloscope," by Harold Jury, Don Lee Television Station W6XAO; April 20, 1943.

MONTREAL

Trip to Factory of Canadian Vickers, Ltd., Montreal; April 24, 1943.

NEW YORK

"Recording from the Air as a Hobby," by T. R. Kennedy, Jr., *The New York Times*; May 5, 1943.
"Need for Signal Corps Officers: Education and Other Requirements, and Procedure for Applying for Commissions," by Lt. Col. K. D. Johnson and Major Theodore Simon, both U. S. Army; May 12, 1943.

PHILADELPHIA

"New York-Philadelphia Television Radio Relay," by F. J. Bingley, Philco Radio and Television Corporation; May 6, 1943.

PITTSBURGH

"Introspective Inventory of an Engineering Education," by R. N. Harmon, Westinghouse Electric and Manufacturing Company; February 8, 1943.
"Broadcast Studio Acoustics," by G. M. Nixon, National Broadcasting Company; March 8, 1943.
"The Electron Microscope," by Dr. C. S. Barrett, Carnegie Institute of Technology; April 20, 1943.

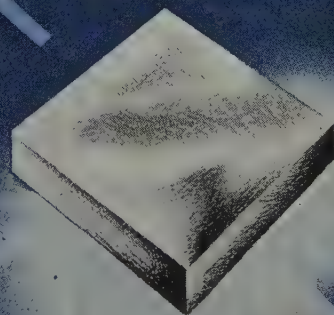
(Continued on page xliii)

BLUEPRINTS OF SAFETY



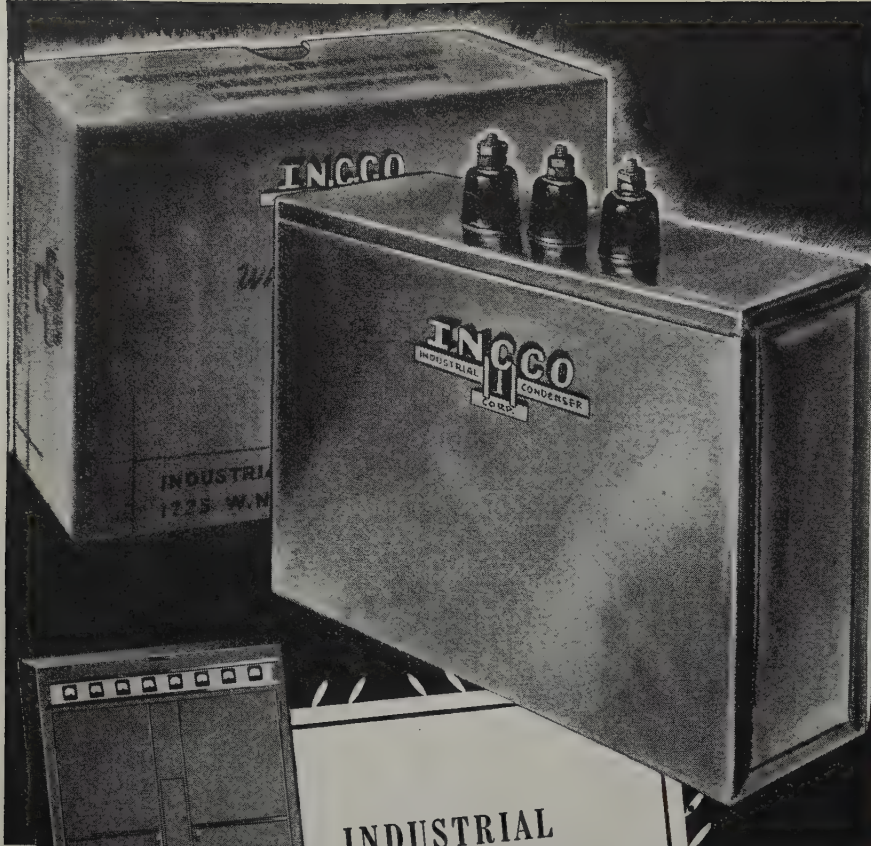
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Section Meetings

(Continued from page xlii)

ROCHESTER

"Noise Measurement with the Sound-Level Meter," by Benjamin Olney, Stromberg-Carlson Telephone Manufacturing Company; April 15, 1943.

"The Conservation of Critical Materials," by Dr. H. S. Osborne, American Telephone and Telegraph Company; May 6, 1943.

"The Conservation of Critical Materials," by E. M. MacDougal, War Production Board; May 6, 1943.

ST. LOUIS

"Rectifier Circuits for Voltage Doubling," by Professor D. L. Waidelich, University of Missouri; April 24, 1943.

WASHINGTON

"Recent Developments in the Design, Testing, and Application of Solid Dielectric Transmission Lines," by Dr. Harner Selvidge, U. S. Office of Scientific Research and Development; May 10, 1943.

Membership

The following indicated admissions and transfers of membership have been approved by the Admissions Committee. Objections to any of these should reach the Institute office by not later than July 31, 1943.

Transfer to Member

Goldman, S., 37 Fairmount Ter., Bridgeport, Conn.

Seaton, S. S., 5241 Broad Branch Rd., N.W., Washington, D. C.

Sziklai, G. C., Maxwell's La., Box 3, Princeton, N. J.

Admission to Member

Cole, D. D., 2 Lindon St., Haddonfield, N. J.

Forsyth, P. G., British Ministry of Supply Mission, 1139 Connecticut Ave., Washington, D. C.

Gunzbourg, P. M., 61 Broadway, New York, N. Y.

Hancock, G. N., 1785 Massachusetts Ave., Washington, D. C.

Toeppen, M. K., 3217 Old Dominion Blvd, Alexandria, Va.

Ziegler, M., Herrera 527, Buenos Aires, Argentina

The following admissions and transfers of membership were approved by the Board of Directors on June 2, 1943.

Transfer to Member

Bennett, R., Radio Division, Bureau of Ships, Navy Dept., Washington, D. C.

Eilenberger, S. D., 6309-13-27 Ave., Kenosha, Wis.

Harvey, H. C., 406 E. Big Bend Blvd., Webster Groves, Mo.

Jutson, R. P., Bell Telephone Laboratories, 463 West St., New York, N. Y.

(Continued on page xlvii)

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other applications.

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Membership

(Continued from page xlv)

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Singelton, H. C., 2005 N. E. 28 Ave., Portland, Ore.
Smith, A. H. R., College of Engineering, Rutgers University, New Brunswick, N. J.

Admission to Member

Davis, S. L., Miller Rd. and Hoyt St., Darien, Conn.
Milne, G. O., c/o Blue Network Co., Inc., 30 Rockefeller Pl., New York, N. Y.
Patrick, K. R., No. 1 Wireless School, Montreal, Que., Canada
Pumphrey, F. H., 4621 23 St., North, Arlington, Va.
Tynan, A. G., 1525 Haynes Ave., Kokomo, Ind.

Admission to Associate

Aderhold, H. J., 111 E. Arlington Hts., North Augusta, S. C.
Allender, F. L., 418—11 St., Dunbar, W. Va.
Bailey, K. D., 331 Beechwood Ave., Norfolk, Va.
Bartholomew, L. E., 57 Dentonia Pk. Ave., Toronto, Ont., Canada
Bassett, F. E., Jr., 1328 Grinnell St., Key West, Fla.
Bennett, A. E., 3304 Forest Lawn Ave., Omaha, Neb.
Bennon, M., 1320 S. 5th St., Philadelphia, Pa.
Berger, M., 221 S. W. Third Ave., Ft. Lauderdale, Fla.
Bierkamp, C. S., Jr., 1413 Wilson Ave., Youngstown, Ohio
Booker, C. C., No. 1 Wireless School, Montreal, Que., Canada
Botticher, G. H. L., 712 N. Penn. Ave., Webb City, Mo.
Brinkman, H. A., 901 S. Washington St., Alexandria, Va.
Brown, W. R., 305 Main St., Toledo, Ohio
Browning, J. H., c/o Fleet P. O., San Francisco, Calif.
Bryant, H. G., Jr., Box 262, Athens, Ga.
Bucher, T. T. N., 1604 Powder Mill La., Wynnewood, Pa.
Bus, B. R., General Electric Co., Nela Pk., Cleveland, Ohio
Callaway, D. E., 433 Ellis St., San Francisco, Calif.
Chan, G., 600 Great North Rd., Auckland, W. 2, New Zealand
Chapman, C. N., 228 Ashworth Ave., Toronto, Ont., Canada
Collins, E. N., Jr., 314 McDowell Rd., Lexington, Ky.
Collins, W. G., 4648 Saratoga Ave., Ocean Beach, Calif.
Colman, A., 21 W. Mosholu Pkwy., N., Bronx, N. Y.
Corcoran, G. F., Elec. Engr. Dept., Univ. of Maryland, College Pk., Md.
Cornwell, R. C., 605 Mt. Prospect Ave., Newark, N. J.
Clutterbuck, E. L., Westinghouse Electric and Manufacturing Co., Third and Elm Sts., Cincinnati, Ohio

(Continued on page xlviii)

So that it won't happen again...

Now, more than ever, let us draw inspiration from our fighting men. Let us work even harder . . . make every required sacrifice . . . give even more of our minds and muscles and means. To pin casualty lists down to minimum, to hasten victory, to perpetuate the peace should be our one and only consideration. Remember—once before we said, "never again"—this time, let's make it stick.

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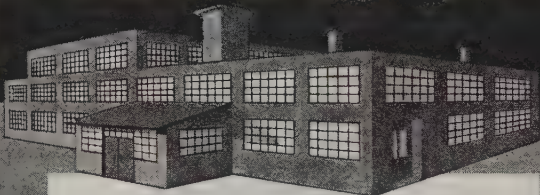
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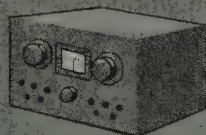
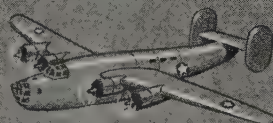
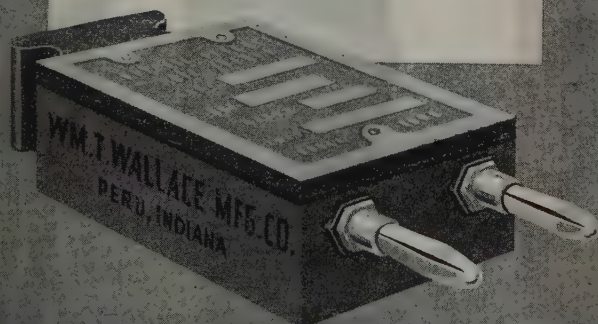


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New books of interest to engineers in radio and allied fields—from the publishers' announcements.

A copy of each book marked with an asterisk (*) has been submitted to the Editors for possible review in a future issue of the Proceedings of the I.R.E.

***ELEMENTS OF RADIO.** By A. Marcus and W. Marcus, prepared under the direction of Dr. Ralph E. Horton • • • *Prentice-Hall, Inc., 70 Fifth Ave., New York, N. Y.* (699 pages+xiii, 6×9½ inches, cloth bound, 504 illustrations.) This book is a basic and elementary home-study course on the fundamentals of radio which requires no advance knowledge of physics and mathematics. The authors state that it was written to the exact prescription of the Government officials responsible for training of thousands of new radio technicians. It is written in simple, non-technical language and appears to fill the need for an extremely elementary but complete text for the radio beginner. Price \$4.00.

***DYNAMICAL ANALOGIES.** By Harry F. Olson, Acoustical Research Director, RCA Laboratories, Princeton, N. J. • • • *D. Van Nostrand Co., Inc., 250 Fourth Avenue, New York, N. Y.* (5½×8½ inches, xi+196 pages, 59 figures, cloth.) The author suggests that "Analogies are useful for analysis in unexplored fields. By means of analogies an unfamiliar system may be compared with one that is better known." This book deals with the analogies between electrical, mechanical rectilinear, mechanical rotational and acoustical systems. The text assumes on the part of the reader a familiarity with the alternating current system and physics. The material and chapters are organized with great clarity and terms are well defined. Price \$2.75.

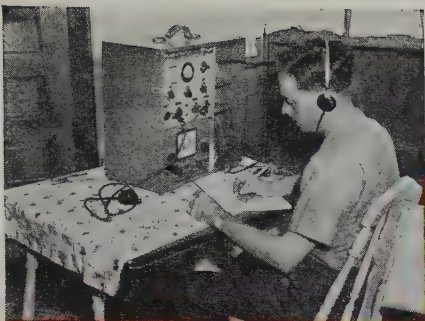
***CYCLOPEDIA OF TELEVISION FACTS.** Compiled by M. N. Beitman, B.S., Radio Instructor, Englewood High School, Chicago • • • *Supreme Publications, 328 S. Jefferson St., Chicago, Ill.* (5½×8½ inches, 60 pages, offset printed from type-written text, 50 illustrations.) This little book is a simple explanation of Television and how it operates. It is done entirely without mathematics and is designed as an introduction to television for high school students or the layman who wants to know more about television. Price \$.40.

***PRINCIPLES AND PRACTICE OF RADIO SERVICING.** (Second Edition) By H. J. Hicks, M.S., Associate Radio Engineer, Aircraft Radio Laboratory, Wright Field, Dayton, Ohio • • • *McGraw-Hill Book Co., 330 W. 42nd St., New York, N. Y.* (6½×9 inches, xii+391 pages, 311 figures, cloth bound.) The author has had fourteen years experience in training men for radio service work, operators for sound motion picture machines and in vocational high schools. The first edition (March, 1939) was designed to teach servicing even up to complicated radio service problems. Mathematics has been reduced to a

(Continued on page 60A)

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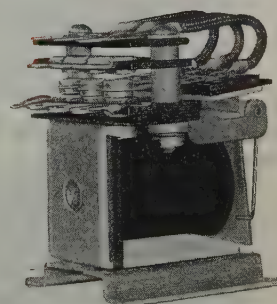
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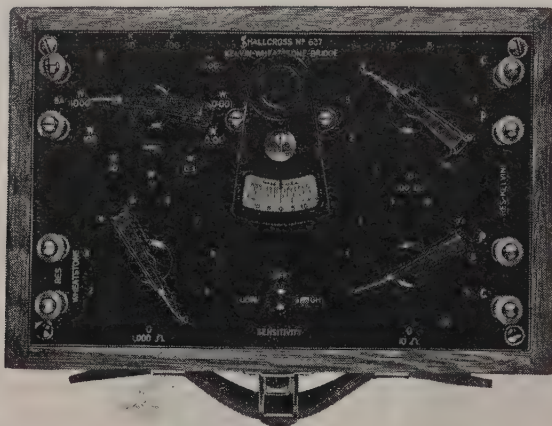
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ATLANTA

"Adjustment of Directional Antennas," by W. S. Duttera (Presented by A. W. Shropshire, Radio Station, WSB); April 16, 1943.

"The Electrical Strength of Nitrogen and Freon under Pressure," by H. H. Skilling and W. C. Brenner (Presented by Ben Akerman, Radio Station WGST); April 16, 1943.

"The Part That the Professional Engineer Plays in the War Effort," by Captain Floyd Fausett, Signal Corps, U. S. Army; May 21, 1943.

BUFFALO-NIAGARA

"Entertainment Radio—After the War: Broadcasters' Angle," by Karl Hoffman "Design Engineers' Angle," by B. E. Atwood; "Retailers' Angle," by A. J. Dykowski; and "Customers' Angle," by Members Present; May 26, 1943. Election of Officers; May 26, 1943.

CINCINNATI

"Radio Broadcast Studio Design," by C. B. Sloan, Crosley Corporation; May 24, 1943.

CONNECTICUT VALLEY

"Design, Testing, and Measurement of Solid Dielectric Transmission Lines," by H. H. Selvidge, Fournier Institute; Discussion of Paper by J. C. Coykendall, E. J. Butler, and R. E. Moe; May 28, 1943.

DETROIT

"Plastics—The New Engineering Materials," by W. B. Hoey, Plastics Processes, Inc.; May 21, 1943.

"Insulating Oils Used in Electrical Equipment," by J. C. Benedict, Detroit Edison Company; June 18, 1943.

LOS ANGELES

"The Mass Spectrometer, An Electronic Method of Chemical Analysis," by Harold Washburn, Consolidated Engineering Corporation; May 18, 1943.

"Available Commissions in the U. S. Marine Corps," by Captain G. H. Wilson, U. S. Marine Corps; May 18, 1943.

MONTREAL

Inspection of Training Facilities at No. 1 Wireless School; May 19, 1943.

NEW YORK

Get-Together Dinner and Smoker-Meeting with F. E. Butler, Guest Speaker; June 2, 1943.

PITTSBURGH

"Tin Flow by Radio-Frequency Heating," by C. J. Madsen, Westinghouse Electric and Manufacturing Company; May 10, 1943.

PORTLAND

"Analysis of the Tuned-Plate Oscillator," by R. M. Lichtenstein, Reed College; Paper Discussed by Messrs. Deardorff, Meissner, and Pritchett; April 22, 1943. "Transmission-Line Theory," by Wilson Pritchett, Oregon State College; Paper Discussed by Messrs. Deardorff and Meissner; May 8, 1943.

(Continued on page 30A)

SELECT for SERVICE



NEW HYTRON TUBES

Type	Description	Price
836	Half-wave, high-vacuum rectifier	\$11.50
837	12-watt, r.f. pentode	2.00
954	Sharp cut-off, acara pentode	4.50
955	Acara triode	2.75
956	Remote cut-off, acara pentode	4.50
1616	Half-wave, high-vacuum rectifier	5.75
1625	25-watt, r.f. tetrode (12-v. heater)	2.50
1626	5-watt, triode oscillator	2.25
E1148	3.5-watt, a-b-4 triode	1.25
VR105-30	Gasos voltage regulator	1.25
VR150-30	Gasos voltage regulator	1.25

Type	Description	Price
2C23	15-watt, medium-mu triode	2.50
2C45	7.5-watt, triode (modulator)	1.50
107	15-watt, general-purpose triode	2.50
001A/001	28-watt, r.f. beam triode	2.25
HY61/007	25-watt, high-mu triode	2.25
841	Non-microphonic voltage-amp. triode	1.00
844	2-watt, power triode	1.50
HY24	30-watt, high-mu twin triode	3.00
HY31Z	15-watt, r.f. beam tetrode	1.75
HY65	40-watt, r.f. beam tetrode	2.25
HY69	15-watt, a-b-4 triode	1.25
HY75	(2C24) 1.8-watt, a-b-4 triode	2.25
HY1148	3.5-watt, a-b-4 triode	2.25
HY615	3.5-watt, a-b-4 triode	2.25

*This is not a complete list.
†Instant-heating filament.
‡For complete characteristics consult Government specifications.



On this list of tubes which have recently joined the growing legions of Hytron types already marching on to Victory, you may find just the ones you want for your War equipments. Whether you choose the tiny "acorns" or the husky 1616 rectifier, you will discover the same high quality and design refinements which have made other Hytron tubes famous. If you place your orders well in advance, you will also be pleased by Hytron's on-schedule deliveries. Not too infrequently, deliveries are made from stock.

HYTRON CORPORATION
NEW HARTFORD, CONNECTICUT
MADE IN U.S.A.
Manufacturers of Radio Tubes



SECTION MEETINGS

(Continued from page 28A)

"Practical Aspects of the Doherty Amplifier," by J. L. Corl, Oregon State College; Paper Discussed by Messrs. Bookwalter, Singleton, and Feikert; May 8, 1943.

ST. LOUIS

"Interference in the Presence of Strong Radio-Frequency Signals," by A. J. Ebel, Radio Station WILL; May 28, 1943.

SAN FRANCISCO

"A War-Time Training Program for Radio Technicians," by Lt. Commander P. J. Fritschel, U. S. Navy Radio Material School; April 22, 1943.

TWIN CITIES

"Ignition Research at Northwest Airlines," by Carl Swanson, Northwest Airlines; May 19, 1943. Election of Officers; May 19, 1943.

MEMBERSHIP

The following indicated Admissions and Transfers of membership have been approved by the Board of Directors on July 21, 1943.

Transfer to Member

Clark, R. G., 9 Christchurch Pl., Epsom, Surrey, England
Dingley, E. N., Jr., Bureau of Ships, Navy Department, Washington, D. C.
Ebel, A. J., 1113 W. Washington St., Champaign, Ill.

Admission to Member

Purgett, L. J., 463 West St., New York City, N. Y.

Admission to Associate

Abraham, G., Naval Research Laboratory, Anacostia Station, D. C. (transfer)
Adams, J. V., Jr., Dept. Signal Office, APO 851, c/o Postmaster, New York, N. Y.
Albersheim, W. J., Bell Telephone Laboratory, Deal, N. J.
Angerbauer, G. J., 926—22 St., Sacramento, Calif.
Arnold, J. B., 2340 Maine St., Quincy, Ill. (transfer)
Baab, H. E., 211 Toledo Ave., Westmont, N. J.
Bader, A., 1447 54 St., Brooklyn, N. Y.
Baird, J. T., Boardsen Rd., Navy Hts., Groton, Conn.
Baker, R. L., 99 Calhoun Ter., San Francisco, 11, Calif.
Barrett, R. E., 132-25-83 St., Ozone Park, L. I., N. Y.
Barnard, R. D., 70 E. Dunedin Rd., Columbus, Ohio

(Continued on page 32A)

Proceedings of the I.R.E. August, 1943



EE8-A

THE EE8-A field telephone is one good reason why American-built communications equipment has a reputation for being the best there is. It is an *unclassified* (not secret) instrument, but we, whose prime war job is to build it, doubt that the enemy can match the EE8-A phone.

You see there *is* a secret to it—the secret of American know-how. For instance:

- How to turn out such delicate, and at the same time, rugged instruments by the tens of thousands, and still have each the equal or superior of a handmade product.
- How to devise instruments to give each unit a complete "laboratory" test, in a few seconds, right on the production line.
- How to make telephones that will operate equally well whether they serve in arctic cold or tropic moisture.

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CONNECTICUT TELEPHONE & ELECTRIC DIVISION



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Meanwhile, there's work to be done . . . important war work . . . and this occupies our immediate attention. It isn't new to us because our experience goes back to the beginning of radio. We've manufactured sound systems, test equipment and numerous electronic devices. We maintain a model organization where management-labor relations are the most cordial . . . making for the highest standards of quality and efficiency. Yes, ECA is busy . . . but, occasionally, our production schedules enable us to take on additional contracts.

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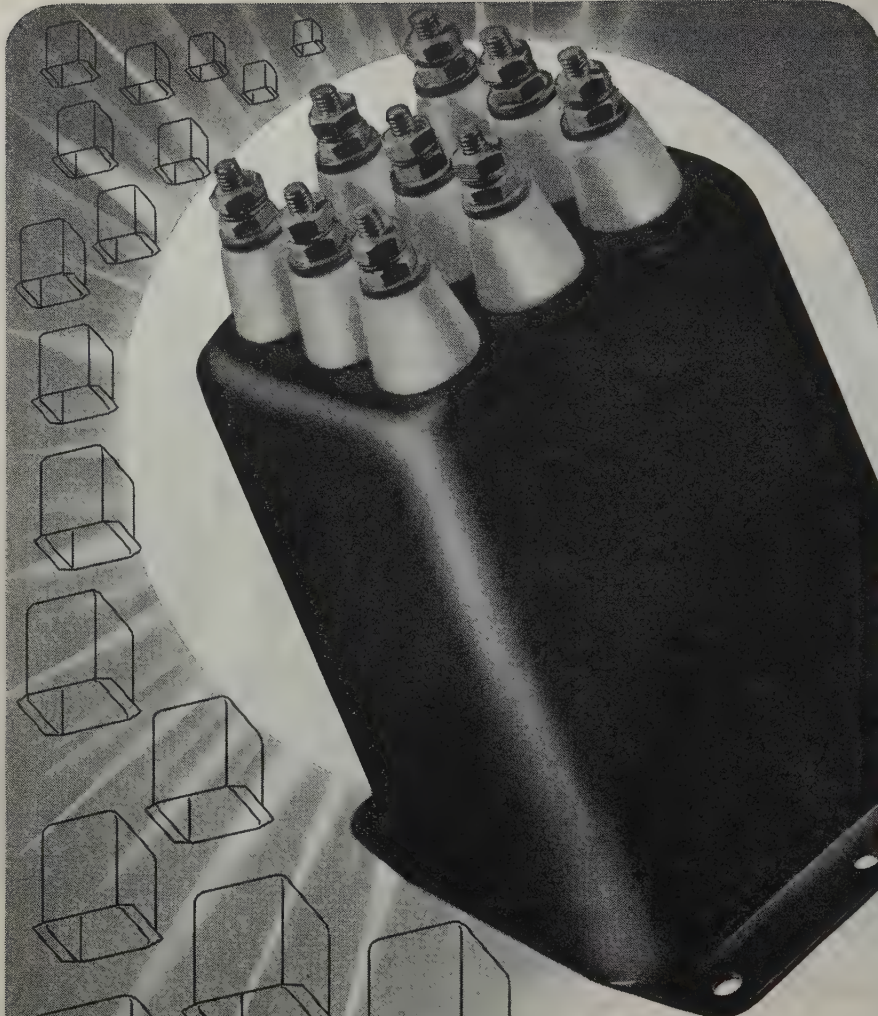
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NEW YORK 11, N. Y.
Watkins 9-1870



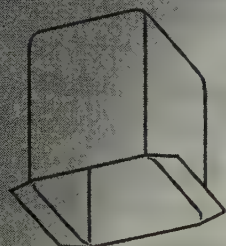
(Continued from page 30A)

- Bastin, M. A., 1435 E. 65 Pl., Chicago, Ill.
 Beltran, A. P., Cochabamba, Bolivia, S. A.
 Bell, D. L., Box 73, New Haven, Ind.
 Berg, R. C., R.F.D. 4, Plantation Rd., Grand Rapids, Mich.
 Bornstein, I., Y.M.C.A., Schenectady, N.Y.
 Brown, A. C., 420 W. 24 St., New York, N. Y.
 Brown, C. M., Box ND 18, 15 Naval District, Balboa, C. Z. (transfer)
 Bryant, R. S., 3 F. St., Miami Homes, McCook Ave., Dayton, 4, Ohio
 Burgett, M. I., Jr., 5722 Green St., Philadelphia, 44, Pa. (transfer)
 Cates, G. R., 129 Bedford Rd., Toronto, Ont., Canada (transfer)
 Chamberlain, P. L., Electronics Dept., General Electric Co., Schenectady, N. Y.
 Chappell, J. F., 108 Davenport St., Detroit, Mich.
 Clapp, C. W., 91 Eileen St., Albany, N. Y.
 Cohen, R. M., 37 Charles St., Belleville, N. J.
 Cole, B. R., RCA Laboratory, Princeton, N. J. (transfer)
 Collette, J. H., 6825 N. Moore Ave., Portland, 11, Ore.
 Conly, E. R., 595 S. Jordan Ave., Ventura, Calif.
 Cooper, R. A., 2212 Silbert Dr., Norfolk, Va.
 Coy, B. A., H.M.C. Dockyard, Esquimalt, B. C.
 Crooks, T. E., 99 Lappin Ave., Toronto, Ont., Canada
 Crump, E. S., 10 Summit St., East Orange, N. J.
 Davidson, H. A., 419 E. Third, Albany, Ore.
 Deaton, C. H., 481 William St., East Orange, N. J.
 Deming, A. F., 203 Glamorgan Ave., Alliance, Ohio
 Ditzler, D., 3357 N.E. Pacific, Portland, Ore.
 Duffy, M. N., 16767 Biltmore, Detroit, Mich.
 Eastman, J. W., F.C.C., 246 U. S. Court House, Chicago, 4, Ill.
 Elmendorf, D. E., Lamp Dept., General Electric Company, Nela Park, Cleveland, 12, Ohio
 Ely, R. L., Jr., Physics Dept., University of Colorado, Boulder, Colo.
 Feiker, G. E., Jr., 75 Willett St., Albany, N. Y.
 Feinman, G., 307 First Ave., New York, N. Y.
 Frank, J. P., 332 Hanison Ave., Lexington, Ky.
 Freeman, J. J., National Bureau of Standards, Washington, D. C.
 Friedman, E. D., 200 Mt. Pleasant Ave., Newark, N. J. (transfer)
 Gable, L. S. H., Rt. 2, Wolf Rd., La Grange, Ill.
 Geren, K. E., 2129 I St., Sacramento, Calif.
 Gersch, H. A., Class 4-44 RMS, Naval Research Laboratory, Anacostia Station, D. C.
 Gilbert, C. W., 52 Hathaway Ct., R.D. 1, Wilkinsburg, Pa.

(Continued on page 34A)



The TOUGHEST TRANSFORMERS have Drawn Steel Cases



A one-piece Drawn Steel Transformer Case without seams or spot welds is, because of its simplicity, the strongest type of mechanical construction. Then, too, the one-piece construction provides a continuous electrical and magnetic path resulting in better shielding from outside electrical and magnetic disturbances. Absence of seams also assures maximum protection against atmospheric conditions—guarantees longer transformer life. If your transformers have to pass the most rigid tests, Potted Transformers in Drawn Steel Cases are probably your answer. Write for information on this Drawn Steel Case line!

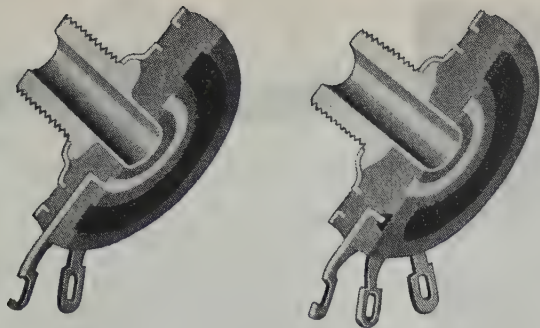
Pioneers of the Compound Filled Drawn Steel Transformer Case



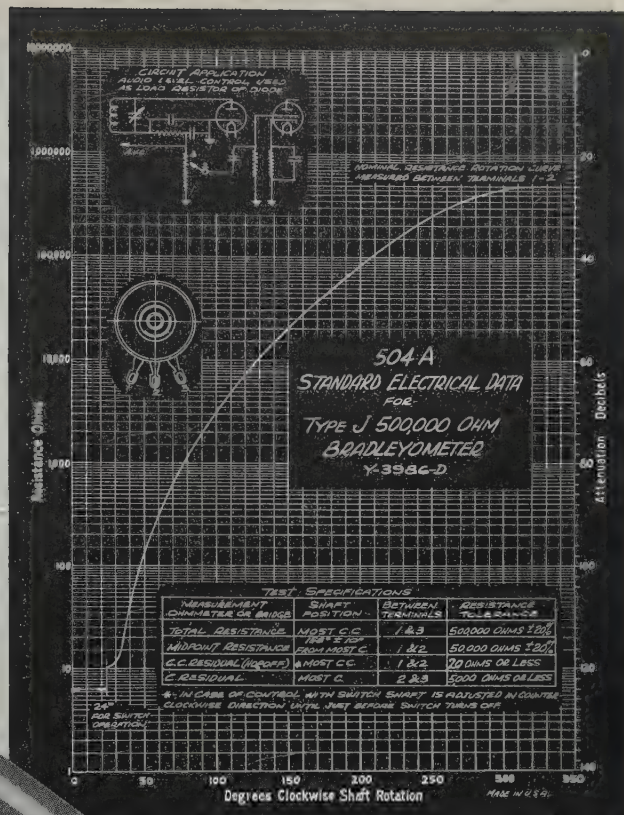
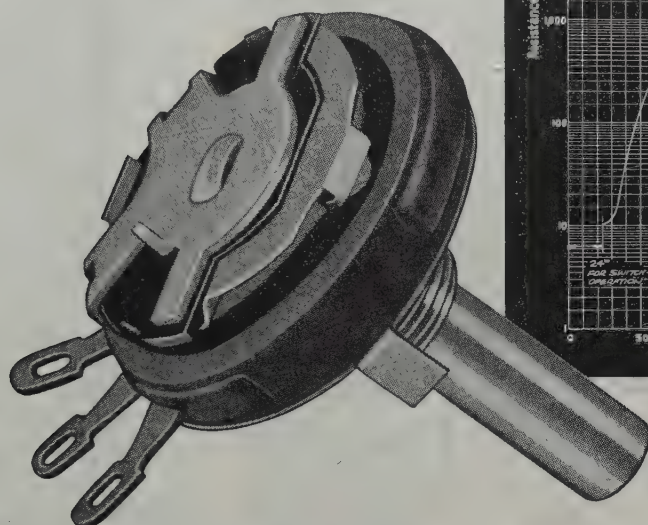
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Cross-section views of Type J Bradleyometers showing how terminals are connected to the solid, molded resistor element.



Here's a variable resistor with the highest safety factor for war service

There's a big margin of safety in the conservative two-watt rating of the Type J Bradleyometer. No other variable resistor of comparable size can meet it. The resistor element is solid and has substantial thickness. It is molded with the insulation, terminals, face plate, and bushing as a single unit, making an exceptionally simple, rugged, and reliable resistor... with no rivets, soldered or welded connections, or painted resistor elements.

During manufacture, the resistor material can be varied throughout the length of the element to provide practically any resistance-rotation curve. Once the unit has been molded, its performance is not affected by heat, cold, moisture, or hard use.



Type JS Bradleyometer with switch.



Type J Bradleyometer without line switch.

The low-resistance carbon brush, which makes a smooth contact with the surface of the molded resistor, assures long life and permanently quiet operation. All these factors make Bradleyometers especially suited for the war conditions, where space is limited and absolute reliability is needed.

Bradleyometers can be used separately or assembled to give dual or triple construction to fit any particular control need. They can be supplied for rheostat or potentiometer applications, with or without a switch. Write for specifications today.



Type EB 1/2-watt insulated Bradleyunit molded fixed resistor.

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee, Wis.



ALLEN-BRADLEY

FIXED & VARIABLE RADIO RESISTORS

QUALITY

(Continued from page 32A)

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- Hutchins, J. F., 208 Blossom Heath Rd., Dayton, Ohio
- Iddings, H. G., Jr., 1824 Rhode Island Ave., N.E., Washington, 18, D. C.
- Janes, A. W., RCA Victor Division, RCA Dept. 671, Harrison, N. J.
- Jensen, L. R., Signal Aircraft Maintenance Section, ARL Bldg., Wright Field, Dayton, Ohio
- Kafafian, H., 35 Delaware Ave., Paterson, N. J.
- Kelly, W. F., 194 Buena Vista Ave., Athens, Ga.
- Kittler, F. W., Naval Research Laboratory, Anacostia Station, D. C.
- Kock, R. E., 154 W. Hancock, Athens, Ga.
- Kolk, G., 98-11 Queens Blvd., Forest Hills, L. I., N. Y.
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- Leon, H. R., 7765 1/2 Hollywood Blvd., Hollywood, Calif.
- Levin, K. L., 550 Forest Ave., Buffalo, N.Y.
- Levy, I. O., 48 Brokersley St., Bow, London, E. 3, England
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(Continued on page 36A)

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ON a hot, steaming jungle isle . . . where at any moment they may hear the whine of a Japanese sniper's bullet . . . men of the U. S. Signal Corps toil incessantly to maintain communication lines. On these slender strands may depend the loss or retention of a vital Pacific outpost . . . success or defeat in a hard war . . . the future of free peoples all over the earth.

This is a war of communication and on the front lines are products manufactured by Utah Radio Products Company . . . with the Navy in Pacific waters . . . with the Air Corps over enemy-occupied territory . . . with the Army on desert sands.

When bullets begin to fly—dependability and non-failing action are indispensable. These qualities have

been built into Utah products at the factory where soldiers of production are working 100% for Victory. In the laboratory, Utah engineers and technicians are working around the clock, developing new ways to meet communication problems—making improvements on devices now in action.

Out of the solution of war communication problems . . . out of the exhaustive research now going on . . . will come sound improvements and new Utah products for the homes and factories of America. Utah Radio Products Company, 842 Orleans Street, Chicago, Ill. Canadian Office: 560 King Street West, Toronto. In Argentine: UCOA Radio Products Co., SRL, Buenos Aires. Cable Address: UTARADIO, Chicago.

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Built with greatest precision and "know how" for **low ripple—high efficiency—low drain** and a **minimum of commutation transients**. High production here retains to the highest degree all the "criticals" which are so important in airborne power sources.

ALLIANCE D. C. MOTORS

Incorporate precision tolerances throughout. Light weight—high efficiency—compactness. An achievement in small size and in power-to-weight ratio. Careful attention has been given to distribution of losses as well as their reduction to a minimum.



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 Martin, M. W., 36 South St., Fairfield, Conn.
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 McGee, H. Q., 4050 N. Hermitage, Chicago, Ill.
 McLean, J. D., Electronics Dept. General Electric Co., Schenectady, N. Y.
 McKey, D. B., Graybar Electric Co., Inc., 420 Lexington Ave., New York, N. Y.
 Merley, G. A., A.A.F. Materiel Command, Hq. Sqdn. Section A., Wright Field, Dayton, Ohio (transfer)
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 Muller, F. A., 740 Riverside Dr., New York, N. Y.
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 Munson, L. J., 918 Noyes St., Evanston, Ill.
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 Naum, L. H., RFD. 1, Krum Kill Rd., Slingerlands, N. Y.
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 Olavarria, E. A., Casilla 1321, Valparaiso, Chile
 Orba, A., Rose Cottage, Moorgreen, Westend, Hants, England
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 Parker, G. I., 1140 Pawtucket Ave., Rumford, R. I.
 Petri, R. E., 6217 N. Bell Ave., Chicago, Ill.
 Pollack, P., Aircraft Radio Laboratory, Wright Field, Dayton, Ohio
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 Price, W. H., 3707 Victory Blvd., Burbank, Calif.
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 Ringland, R. S., 13 Miles Standish Rd., Schenectady, N. Y.
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 Robin, H. L., 29 W. 70 St., New York, N. Y.
 Rollin, L., 69 Willows La., Firgrove, Rochdale, Lancs, England
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 Savory, W. N., Naval Research Laboratory, Anacostia Station, D. C.

(Continued on page 38A)



Towers that talk . . .

Tall towers of slender steel. A spider web of steel flung across the sky. A small building. Nothing more.

Nothing more?

Much, much more—for this is radio. And in radio as in man, the things unseen count most. Like the power of the human spirit, the energy of radio is invisible.

From the silence of these towers come the ringing words of patriot radio speakers—the lilt and lift of radio music—the saving grace of radio drama—the instruction and counsel of radio teachers and advisors—the linking of the people's needs and aspirations with the services of America's manufacturers and merchants.

This is the work of America's broadcasters, in which RCA is proud to assist. Through years to come radio broadcasting will render service now but dimly realized—not only in standard broadcast, but in FM, television, and

facsimile—in these, too, RCA's special knowledge, extensive facilities and tireless research will play their part.

RCA's resources are today concentrated on war production. Yet RCA engineers are still available to help you solve your pressing technical problems. To the fullest extent possible under war conditions we shall continue to supply and service the vitally important broadcasting industry.



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(Continued from page 36A)

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- Schwerman, J. F., 312 W. Sixth St., Lexington, Ky.
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- Stiber, S., 1 Lane St., Long Branch, N. J.
- Stopher, H., 36 Pleasant Grove, Shirley, Croydon, Surrey, England
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- Suarez, E. F., Planta Electrica, San Juan, Republica Dominicana
- Sutto, J. F., APO 629 c/o Postmaster, New York, N. Y.
- Thogersen, G. O., 23-24—28 St., Long Island City, L. I., N. Y.
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- Walker, W. D., 4424 Elliot Ave., Dayton, Ohio
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- Watterson, C. C., Naval Research Laboratory, Anacostia Station, D. C.
- Weaver, A., Bell Telephone Laboratories, 180 Varick St., New York, N. Y.
- Webb, E. E., Electronics Training Group, 2K Santander Apts., A.P. Area, Ft. Monmouth, N. J. (transfer)
- Weedman, W. F., Special Development Section, Naval Research Laboratory, Anacostia Station, D. C.
- White, M. W., Naval Radio Station Dupont, Charleston, S. C.
- Wilewski, H. M., 67 Stockman Pl., Irvington, N. J.
- Wolke, R. K., 9034—176 St., Jamaica, L.I., N. Y.
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... but, to say that there is only one MYCALEX is not sufficient without the backing of fact. Whatever claims are made have been proved in actual "firing line" application throughout the far corners of the globe. Through intense heat and cold ... in days before the war, and in these critical times, MYCALEX has emerged predominant in its field and, as leading engineers in industry, radio and television have told us, "*is the most nearly perfect electrical insulator known today.*"

These engineers specify MYCALEX because they prefer MYCALEX. Extremely versatile in its application, it may be cut, drilled, tapped, machined, milled,

ground, polished and moulded. It meets requirements for close tolerances. Moreover, MYCALEX is leadless. This, combined with low loss at all frequencies, gives it advantages over all other types of glass bound mica insulation.

MYCALEX is not the name of a class of materials, but the registered trade-name for low-loss insulation manufactured in the Western Hemisphere only by the *Mylex Corporation of America*. Be sure to specify MYCALEX if you are looking for low power factor, low loss, negligible moisture absorption and high dielectric strength. *Sheets and rods immediately available for fabrication by us or in your own plant.*

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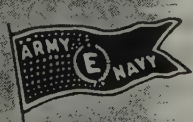

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That explains why Thordarson engineers...
in good times or in bad... in peace-time, or in
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Seaton, S. L., 5241 Broad Branch Rd., N.W., Washington, D. C.
Sziklai, G. C., Maxwell's La., Box 3, Princeton, N. J.

Admission to Member

Cole, D. D., 2 Lindon St., Haddonfield, N. J.
Forsyth, P. G., British Ministry of Supply Mission, 1139 Connecticut Ave., Washington, D. C.
Gunzbourg, P. M., 61 Broadway, New York, N. Y.
Hancock, G. N., 1785 Massachusetts Ave., Washington, D. C.
Toeppen, M. K., 3217 Old Dominion Blvd., Alexandria, Va.
Ziegler, M., Herrera 527, Buenos Aires, Argentina.

Admission to Associate

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Auditore, C. J., Patterson Field, Fairfield, Ohio
Baker, W. H., 146 N. LaPorte Ave., Chicago, 44, Ill.
Baldwin, T. W., 107-39 Princeton St., Jamaica, L. I., N. Y.
Barrick, C. M., 1346 Maple St., Santa Ana, Calif.
Bartman, F. L., 554 N. Maple Ave., East Orange, N. J.
Beadle, D. G., The Cottage, Plaxtol, Sevenoaks, Kent, England
Bergmann, H. M., 205 Edgewood Ave., New Haven, Conn.
Berlin, W. H. V., 1318-29 St., San Diego, 3, Calif.
Bittner, E. J., Poyners Hill, Poplar Branch, N. C.
Brewer, L. F., 2019 Conn. Ave., N.W., Washington, 8, D. C.
Brough, A. E., Hq. Box 3246, Seattle 14, Washington.
Brown, J., 2055-38 St., S.E., Washington, D. C.
Brown, L. L., c/o Fleet Post Office, New York, N. Y.
Bruns, J. E., 1222 Ten Oaks Rd., Arbutus, Md.
Buestrin, L. P., Radio Material School, Naval Research Laboratory, Anacostia Station, D. C.
Bulger, J. F., 56 Churchill St., Milton, 87, Mass.
Butler, H. J., 1514 Ralworth Rd., Baltimore, Md.
Callanan, J. A., 6825 N. Olcott Ave., Chicago, 31, Ill.
Chamberlain, P. E., 405 E. Fourth St., O'Fallon, Ill.
Chertok, S. L., Box 328, Red Bank, N. J.
(Continued on page 36A)



Even the Big Inch Needs IRC RESISTORS

Vital arteries of supply in this mechanized war are America's pipelines. To maintain capacity flow, sludge and gummy deposits must be cleaned out at intervals. For this purpose a screw-type

ANOTHER **IRC** DEVELOPMENT

scraper propelled by the oil pressure is employed. When occasionally the scraper becomes stuck and plugs the line, the point of stoppage must be located to release the flowing oil. But where—and how?

With the use of the Geiger-Mueller Counter, hours—and sometimes days—of search are saved. Modern scrapers contain radio-active metal which con-

stantly emits an impulse message. When trouble occurs, these signals are picked up by the Counter, as the line is checked. At the point of greatest intensity the pipeline is tapped and the obstruction cleared away.

IRC engineering ingenuity plays an important part in the functioning of Geiger-Mueller Counters. Many specially designed IRC resistors and controls are employed in their carefully adjusted circuits.

If you have a design or engineering problem involving resistance units and you are seeking unbiased advice, why not come to Resistor headquarters at IRC? We make more types of resistors, in more sizes, for more applications than any other manufacturer in the world.



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Keep 'Em Running FOR THE DURATION!

It is difficult to secure new Generating Sets or new Rotary Converters... Pioneer is devoting all of its resources toward winning the war... but we can, and will, help you keep your present equipment running for the duration. Send your service problems, by letter, to Pioneer's Customer Service Department.

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- Cohen, O., 6550 S. Justine St., Chicago, 36, Ill.
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- Day, E. C., 16 W. Mystic Ave., Mystic, Conn.
- Dean, W. W., 526—21 St., Schenectady, 4, N. Y.
- DeLucia, E. V., 34 Halloween Blvd., Stamford, Conn.
- Deutach, K. T., 1000 Brannan St., San Francisco, Calif.
- Dinzl, R. A., 648 Nottingham Pl., Westfield, N. J.
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- Dunn, H. C., Creek Rd., Marshallton, Del.
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- French, H. M., A.R.R.L., 38 LaSalle Rd., West Hartford, Conn.
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- Gilbert, J. A., 1584 North Lake Ave., Pasadena, 6, Calif.
- Godfrey, E. H., 32 St. Mary's Ave., Finchley, England
- Gossland, J. K., Bell Laboratories School, 250 Hudson St., New York, N. Y.
- Gracely, F. R., Radio Section, National Bureau of Standards, Washington, D. C.
- Greene, R., 12 C Crescent Rd., Greenbelt, Md.
- Griffith, B. D., c/o Fleet Post Office, San Francisco, Calif.
- Gross, E. E., General Radio Co., 30 State St., Cambridge, Mass.
- Grow, R. E., ARES Rodgers Bldg., Franklin and Ludlow Sts., Dayton, Ohio

(Continued on page 38A)



Radio after the **WAR**

what price Star-Gazing?

To dream and plan realistically for the future is both good and necessary. However, to indulge in Star-Gazing through the wrong end of the telescope is an extravagance which no industry can afford. RADIO can point with pride to its achievements and its miraculous progress made under the impetus and emergency of war. But to promise that the miracles of Wartime Electronic development will be ready for delivery on V-Day . . . is to damage an otherwise glorious record.

THE FUTURE IS BRIGHT . . .

BUT LET'S KEEP OUR EYE ON THE BALL!

Our number one job right now is the production of Radio Communications Equipment for our armed services. These are weapons which will help win the war. The application of new Electronic knowledge to peacetime radio production will, of necessity, be a gradual and evolutionary process. We know too that Electronic research and development now entirely serving our war effort can and will elevate every phase of human living.



For the development and production of Radio Communications Equipment for our armed forces, the Motorola organization was awarded the Army-Navy "E" with added Star for continued excellence of performance. Motorola is proud of the part it has been privileged to play in the speeding of Victory.

You May Expect Big Things from Motorola. We can't say when but we can say . . . no one will be ready sooner!

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RADIO
FOR CAR & HOME

MANUFACTURING CORPORATION • CHICAGO

★ ★ ★ ★ ★ ★ ★

INTEGRITY of DESIGN

... a plus feature of all Jackson Instruments

NO MATTER what your requirements for measurement of voltages, currents, and other values, the JACKSON Model 642 Multimeter will serve you well. This highly sensitive DC volt meter has ranges up to 5,000 volts . . . also complete AC voltage ranges; also provision for ohm measurements up to 30 megohms. Other ranges are DC milliamperes, DC microamperes, DC amperes and decibels.

In daily use, in Industrial and Development Laboratories — as well as in the Armed Services the world over—the INTEGRITY of DESIGN, and basic high quality of this Instrument, has been thoroughly proved.

Another triumph of JACKSON engineering and INTEGRITY of DESIGN (also shown below) is the Audio Frequency Oscillator Model 652. This Instrument operates on the resistance-capacity tuned principle . . . has splendid stability . . . continuous frequency range from 20 to 20,000 cycles with excellent wave form. Model 652 is simple in operation, gives positive, trouble-free results; and is fulfilling a critical, full-time war job.

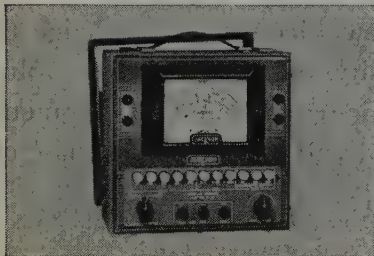
Production of JACKSON Instruments has been vastly in-



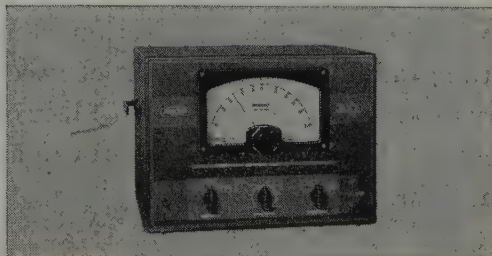
creased to meet urgent military needs. All JACKSON equipment continues available, subject to W.P.B. regulations. Write for catalog—and for an explanation of the full meaning of INTEGRITY of DESIGN.

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All Jackson employees—a full 100%—are buying War Bonds on a payroll deduction plan. Let's ALL go all-out for Victory.



Model 642 Multimeter



Model 652 Audio Oscillator

JACKSON

Fine Electrical Testing Instruments

JACKSON ELECTRICAL INSTRUMENT COMPANY, DAYTON, OHIO



(Continued from page 36A)

- Guttman, I., 15 Lakeview Rd., Deal, N. J.
- Harrison, A. A., 227 Newton Ave., Glen Ellyn, Ill.
- Hartley, M. S., Navy Office of Canada, 10 Haymarket St., London S.W.1, England
- Hastings, L. E., Federal Communications Commission, 404 Federal Bldg., Galveston, Texas
- Herrmann, F. J., 220 Cooper St., Camden 2, N. J.
- Herrmann, F. W., 4224 Drew Ave., S., Minneapolis, Minn.
- Hess, D. C., Jr., 8 Victory St., Aberdeen, Md.
- Hibbert, J. J., 44 Amsden St., Arlington, Mass.
- Hill, W. A., Jr., 1905 Bransford Ave., Nashville, Tenn.
- Hodges, M. F., 1723 Irving St., N. W., Washington, D. C.
- Huevner, G. L., Jr., 222 E. 57 St., New York, N. Y.
- Jacobsen, L. H., Box 565, Koloa, Kauai, T. H.
- Johnson, R. C., 2139 Penna. Ave., N.W., Washington, D. C.
- Karr, P. R., 3935 Newdale Rd., Chevy Chase, Md.
- Kelar, J., 52 South Walnut St., East Orange, N. J.
- Kelly, G. B., Airways, Kelly Field, Texas
- Kershner, S. W., 415 Third Ave., Asbury Park, N. J.
- King, L. A., Clemson College, Clemson, S. C.
- Klepper, A., 185 Erasmus St., Brooklyn, N. Y.
- Koleda, J. T., 114-15—128 St., Richmond Hill, L. I., N. Y.
- Kimball, R., 134 W. Colorado St., Pasadena, Calif.
- Langford, J. W., Jr., 23 Beech Ave., Aldan, Delaware County, Pa.
- Lauer, H., Plaza Hotel, Camden, N. J.
- Lear, P. R., 31 Hampton, Court Ave., East Molesey, Surrey, England
- Lewis, C., 4020 Mt. View Dr., Bremerton, Wash.
- Loeb, L. S., 240 A Avenue, National City, Calif.
- Long, A. W., 143 Hallock St., Riverhead, L. I., N. Y.
- Long, L. E., 148 W. Norman Ave., Dayton, Ohio
- Lovejoy, R. E., 712 Yuma St., S.E., Washington, 20, D. C.
- Marcinkowski, C. J., 1327 Fenwick La., Silver Spring, Md.
- Marshall, J. W., APO 869, c/o Postmaster, New York, N. Y.
- Marshall, T. A., 82 Daisy Ave., Floral Park, L. I., N. Y.
- Marzetta, L. A., Naval Research Laboratory, North Beach, Md.
- McElwain, J. L., Big Spring Heights, Newville, Pa.
- MacGillivray, J. A., 2950 Vieuxmont Ave., Montreal, Que., Canada
- McFarlane, D. J., 2 Bonad Rd., Winchester, Mass.

(Continued on page 42A)

Unexcelled for Lightness



FURTHER FACTS FOR ENGINEERS ABOUT MYKROY'S SUPERIOR INSULATING QUALITIES

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6.68.....	Dielectric Constant	(Dry).....	6.75
6.73.....	Dielectric Constant	(Wet).....	6.70
.00240.....	Power Factor	(Dry).....	.00164
.00241.....	Power Factor	(Wet).....	.00231
1.60.....	Loss Factor	(Dry).....	1.11
1.62.....	Loss Factor	(Wet).....	1.54
630 Volts per Mil.....	Dielectric Strength		660 Volts per Mil.

No. 8

From Reports of Independent Testing Laboratories

ONE SQUARE INCH* of this fine glass bound mica insulating material weighs only .013 lbs. Yet MYKROY'S mechanical strength is comparable to that of cast iron.

This exceptional lightness factor in a ceramic insulator is a strategic advantage—especially in applications where a minimum of weight is vital to swift and easy mobility. Hence MYKROY is becoming a familiar part of such instruments as "Walkie-Talkie" and aircraft electronics devices.

If your equipment demands the most advanced and efficient insulation, let us demonstrate the specific advantages and uses of MYKROY.

* 1/8 inch thick.

MYKROY IS SUPPLIED IN SHEETS AND RODS . . . MACHINED OR MOLDED TO SPECIFICATIONS

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WHEN the squadron leader snaps instructions into his microphone, it's not time for doubt or confusion on the receiving end.

In manufacturing headsets for the use of our fighting forces, the main thing is to be certain each one is as perfect as it is possible to make it.

Experience since the early days of the telephone helped us, of course, but it wasn't enough to be sure that we were building mighty good equipment *on the average*. We developed special instruments which enable us to give each receiver a thorough test in a matter of seconds, right on the production line. Thus we kept output high, and quality a *known* factor.

Connecticut has been identified with "communications" for half a century. It has never been known as the largest, but always as among the very best, in design, engineering, and precision production. If your post-war plans involve the use of precision electrical devices, in connection with product development or production control, perhaps we can help you eliminate the "question marks".

CONNECTICUT TELEPHONE & ELECTRIC DIVISION



MERIDEN,

CONNECTICUT



For the second time within a year, the honor of the Army-Navy Production Award has been conferred upon the men and women of this Division.

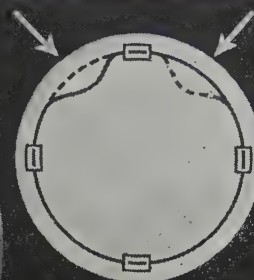


(Continued from page 38A)

- McNall, J. W., Research Department, Westinghouse Lamp Division, Bloomfield, N. J.
- Medill, J. W., 351 Garfield Ave., Valparaiso, Ind.
- Minnett, H. C., Radiophysics Laboratory, City Rd., Chippendale, Sydney, N.S.W., Australia
- Murtough, W. L., 70 Bingham Ave., Rumson, N. J.
- Moss, J. F., 118 North Clark Dr., Los Angeles, Calif.
- Navas, Y. F., 35-06—165 St., Flushing, L. I., N. Y.
- Nielsen, G. A., c/o Postmaster, San Francisco, Calif.
- Nightenhelser, K. W., 18 S. Cherrywood Ave., Dayton, Ohio
- Olmsted, J. M., 1101 Riverside Dr., Dayton, Ohio
- Olsen, W. E., R.F.D. 422, Riverhead, L. I., N. Y.
- Perkins, G. D., 212 Central Ave., Dayton, Ohio
- Pierson, C. D., Jr., 1717 Summerdale Ave., Chicago, Ill.
- Pike, D. E., Research Department, Farnsworth Television and Radio Corp., 3700 E. Pontiac St., Ft. Wayne, Ind.
- Ramanna, R., 1792 Pardmalaya, Sampige Rd., Malleswaram, P. O., Bangalore City, India
- Post, B. M., 1401 N. LaSalle St., Indianapolis, Ind.
- Pratt, G. W., 899 Pleasure Rd., Lancaster, Pa.
- Pueschner, H. O., 558 N. Oakland Ave., Indianapolis, Ind.
- Pummill, J. S., Aircraft Radio Engineering School, 355 S. Main St., Dayton, Ohio
- Reed, H., 3917 Madison St., Hyattsville, Md.
- Reynolds, F. L., 41 Westfield St., Rochester, 11, N. Y.
- Risenburg, L. C., 554 Tonawanda St., Buffalo, 7, N. Y.
- Rosenblum, B., 5 Wadsworth Rd., Greenford, Middlesex, England
- Rosentreter, E. W., Bldg. U., General Electric Co., West Lynn, Mass.
- Schach, A., Templetone Radio Co., Mystic, Conn.
- Schart, W. J., 425 Grand Ave., No. 3., Dayton, 5, Ohio
- Schuster, C. A., 193 Second St., Clifton, N. J.
- Shawhan, E. N., 2012 Ft. Davis St., S.E., Washington, 20, D. C.
- Shepard, B. R., 902 Delamont Ave., Schenectady, N. Y.
- Sicuranza, C. A., 4848 Broadway, New York, N. Y.
- Smith, E. H., 1620—14 Ave., Seattle, 22, Wash.
- Smith, T. O., 6814 Dartmouth Ave., College Park, Md.
- Smith, W. T., 138 Orchard St., Newark, N. J.

(Continued on page 44A)

ACTUAL-SIZE
ILLUSTRATIONS



INDENTS
FACILITATE
TAPPING
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TURN!

No. 1590

Single winding with indents. Weight complete, only 3¼ ounces. Coil 2" diam. x 4" long. 3¼" overall height.

No. 1591

Double winding (tapped outer coil with inner winding for coupling to a low-impedance load). Weight complete, 2¾ ounces. Coil 2" diam. x 3" long. 3¼" overall height.

MADE "SPECIAL"—MADE FAST— and MADE RIGHT!

These two Air-Wound units, designed for ship-to-shore radio telephone transmitters, are typical of B & W small coils now being produced to meet exacting specifications by modern production methods *at the rate of 1200 a day!*

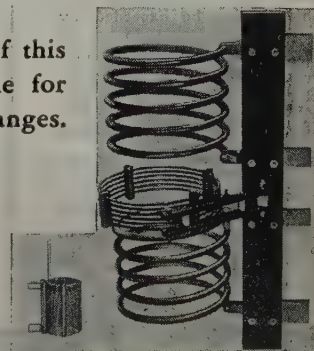
Many outstanding advantages accrue to these coils as a result of the famous B & W Air-Wound construction: Exceptionally light weight; mechanical ruggedness (they are not

likely to be put out of commission by dropping or rough handling); adaptability to design or engineering changes in laboratory or field use; and the ease with which *ANY* of the closely-wound turns may be tapped, thanks to the special indent feature.

B & W Air Inductors of this general type are available for all normal frequency ranges. Literature on request.

BIG COILS, TOO! →

Here you see the small No. 1591 Air Inductor shown in comparison to a B & W high-power unit for 10 KW. service. Details on any type gladly sent.

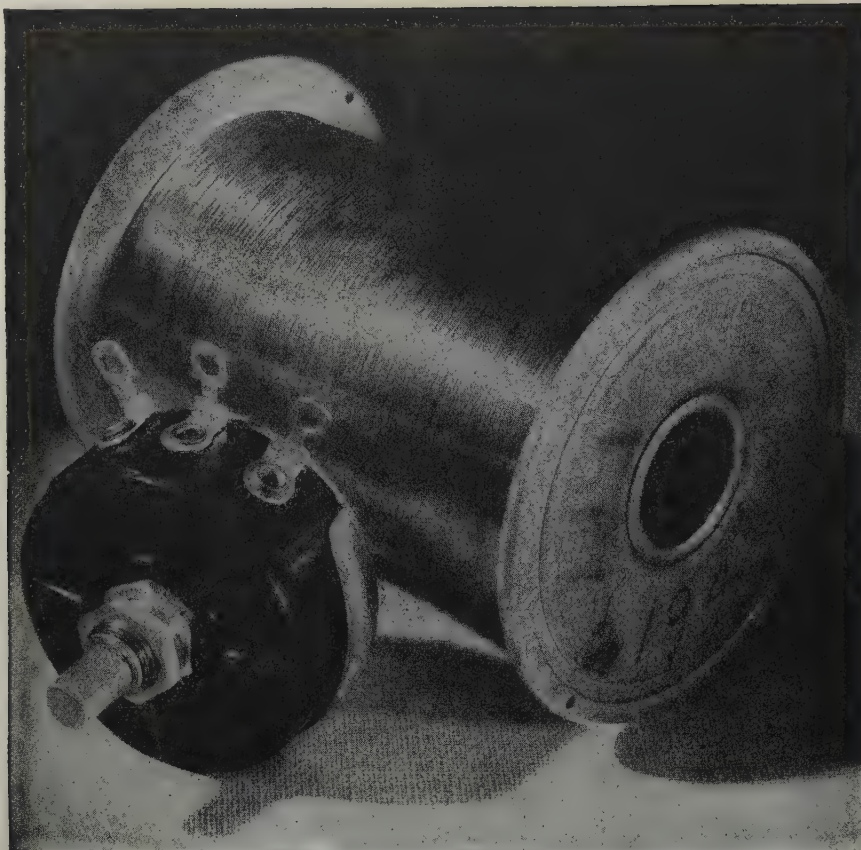


B&W

AIR INDUCTORS

Air-Wound and Ceramic and Phenolic Form Types

BARKER & WILLIAMSON, 235 Fairfield Ave., Upper Darby, Pa.



Wire-wound rheostats and potentiometers Type 58 shown above. 1 to 100,000 ohms. Choice of tapers. Linear, rated at 3 watts; tapered, 1.5 and 2 watts.

★

Multiple controls up to 20 units in tandem. Single shaft locks with rotor of each control. Interlocking resistance ratios provide any desired voltage or current at given degree of rotation, for each circuit.

★

Power rheostats in 25- and 50-watt ratings. 0.5 to 10,000 ohms. Exceptionally rugged. Normal current may be exceeded by 50% at any setting up to 1/3 rotation. Also available in tandem combinations. Special units made in strict accordance with Army and Navy Air Force specifications. Enclosed or armored units.

★

Also other types of wire-wound controls, standard and special, to meet all needs.

WIRE-WOUND

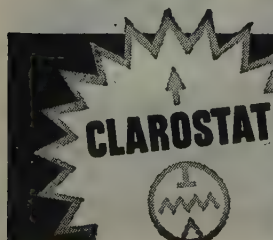
Controls

★ A 300% increase in winding capacity! This feature of Clarostat's recent production expansion climaxed by the opening of a second plant, is a vital contribution to the war effort. Please bear this wire-winding capacity in mind in connection with your high-priority requirements.

And remember also that for the past two decades Clarostat engineers have designed, built and steadily refined their *exclusive* winding machines. Marvels of mechanical ingenuity, these machines produce those precise windings of uniform or variable pitch; those round, square or flat windings; those tricky multiple-tapped windings; those high-ohmage windings requiring wire even as fine as .0009" (nine ten-thousandths—finer than human hair). All of which explains why most *really tough* control jobs usually come to Clarostat.

★ *Send Your Problem . . .*

If it deals with adjustable or fixed resistance send it to us for engineering collaboration, specifications, quotations. Literature on request.



Controls and Resistors

CLAROSTAT MFG. CO. Inc. - 285-7 N. 6th St., Brooklyn, N. Y.



(Continued from page 42A)

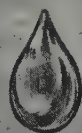
- Stahl, P. D., 1700 Bathgate Ave., New York, N. Y.
 Stephenson, I., 25 Springfield Pl., Bradford, Yorkshire, England
 Taidhoff, S. J., National Press Bldg., Washington, D. C.
 Taussig, O. C., 407 Sanders Ave., Schenectady, N. Y.
 Threadgill, A. R., 96 Goodrich Ave., Lexington, 33, Ky.
 Thurston, W. R., 111 Bay State Rd., Boston, 15, Mass.
 Unger, R. M., 295 Exchange St., Millis, Mass.
 Van Aller, H. T., c/o R.M.O. Office Roof Bldg. 3, Brooklyn Navy Yard, N. Y.
 Van Ryn, B., 29 Shrublands Close, Chelmsford, Essex, England
 Wardale, A. H., 25 Waratah St., Bexley, N.S.W., Australia
 Ware, W. H., c/o Hazeltine Electronics Corp., Little Neck, L. I., N. Y.
 Webster, C. J., 1116 South Washington St., Aberdeen, S. D.
 Weimer, P. K., 359 Nassau St., Princeton, N. J.
 Wilson, G. C., Morristown Y.M.C.A., Morristown, N. J.
 Wolfram, W. R., 412 S. Knight Ave., Park Ridge, Ill.
 Yaffee, P., 317 Third St., S.E., Washington, 3, D. C.
 Youtz, P., 7250 Bennett Ave., Chicago, Ill.
 Young, C. R., 2252 Kenilworth Ave., Los Angeles, Calif.
 Zeldin, S. L., 1719 Townsend Ave., New York, N. Y.

The following indicated admissions and transfers of membership have been approved by the Admissions Committee. Objections to any of these should reach the Institute office by not later than October 31, 1943.

Transfer to Member

- Bronwell, Arthur B., Northwestern University, Evanston, Ill.
 Breazeale, Dr. William M., Radiation Laboratory, Cambridge, Mass.
 Chipp, Rodney D., 4805—14th St., N.W., Washington, D. C.
 Epstein, D. W., RCA Laboratories, Princeton, N. J.
 Gibson, William Thomas, Lopen House, Seavington, Somerset, England
 Hector, Dr. L. Grant, 57 State St., Newark, N. J.
 Hunt, Albert Brewer, Box 369, Montreal, Que., Canada
 Jenks, David W., Electronic Tube Engineering Division, General Electric Co., Schenectady, N. Y.
 King, Ronold W. P., Cruft Laboratory, Cambridge, Mass.
 Lidbury, Frank Austin, Box 346, Niagara Falls, N. Y.
 Nicoll, Frederick H., RCA Laboratories, Princeton, N. J.

(Continued on page 46A)



VITAL

... as a drop of rain

Spirit . . .

Our enemies, who lack among their own peoples an idealism that motivates the individual from within rather than one forced upon him, are increasingly learning to count the cost of their gross ignorance and accordingly miscalculating that tremendous VITAL force — AMERICAN SPIRIT! Just as American Spirit is helping forge victories on the field of battle, so does American Spirit on the production front provide the priceless ingredient which, added to materials and skills, results in our unprecedented output.



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(Continued from page 44A)

Paddon, John Wreford, Canadian Department of Munitions and Supply, Washington, D. C.

Pollack, Dale, Groton Long Point, Conn.
 Shanck, Roy B., 134 Manor Road, Douglaston, L. I., N. Y.

Silver, McMurdo, 140 E. 28 St., New York, N. Y.

Admission to Member

Barker, P. L., Grafton Hotel, Connecticut Ave., Washington, D. C.

Levy, Sol J., 600 Fourth Ave., Bradley Beach, N. J.

McCreary, Harold J., 320 Lewis Ave., Lombard, Ill.

Moore, James R., Box 12, Dutch Neck, N. J.

Ryder, Robert M., Bell Telephone Laboratories, Murray Hill, N. J.

The following admissions to membership were approved by the Board of Directors on September 8, 1943.

Admission to Associate

Allard, E. V., Jackson Bldg., Ottawa, Ont., Canada

Anderson, W. M., 4800 Oakland Ave., Minneapolis, 7, Minn.

Androvich, C. N., 216 Ocean Pkwy., Brooklyn, N. Y.

Armstrong, C. W., 45 Merion Rd., Merchantville, N. J.

Armstrong, C. A., 1001 S. Columbus St., Arlington, Va.

Bassette, C. S., Box 468, Tuskegee Institute, Ala.

Birdsong, H. S., Barracks 55, USATTC, Memphis, Tenn.

Boland, R. K., 223-14 Ave., S.E., Rochester, Minn.

Brower, D. F., Co. B, 2510 Service Unit, AST, University of Maryland, College Park, Md.

Charp, S., 6228 Pine St., Philadelphia, Pa.

Clement, B. R., 36 Violet Ave., Mineola, L. I., N. Y.

Clements, B. C., Ste 1-5 48 Bayfield St., Barrie, Ont., Canada

Cohen, J. E., 67 Roosevelt Dr., Middletown, Conn.

Collar, H. W., 1221 Wayne Ave., Dayton, Ohio

Combs, E. C., 3419 Champion St., Oakland, Calif.

Cottrell, B. P., Western Electric Co., Radio Division, 195 Broadway, New York, N. Y.

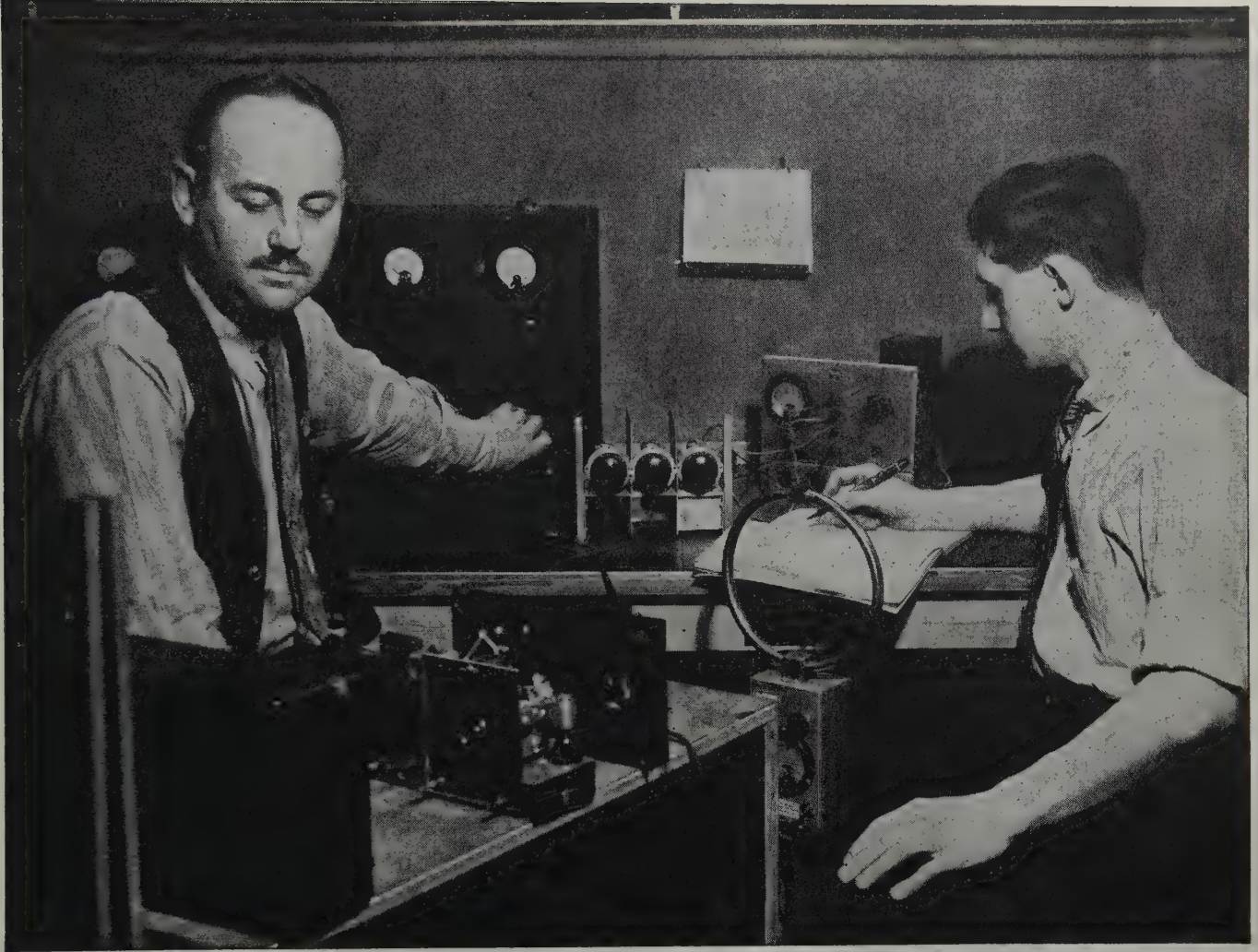
Courtney, J. M., 1400 Chestnut, Kansas City, 1, Mo.

Cox, A. E., Apt. 2, 300-34 St., S.E., Washington, D. C.

Creveling, R., 1726 Mound St., Springfield, Ohio

Dettman, M. C., 9527 Glenwood Rd., Brooklyn, N. Y.

(Continued on page 48A)



Performance Perfectionists

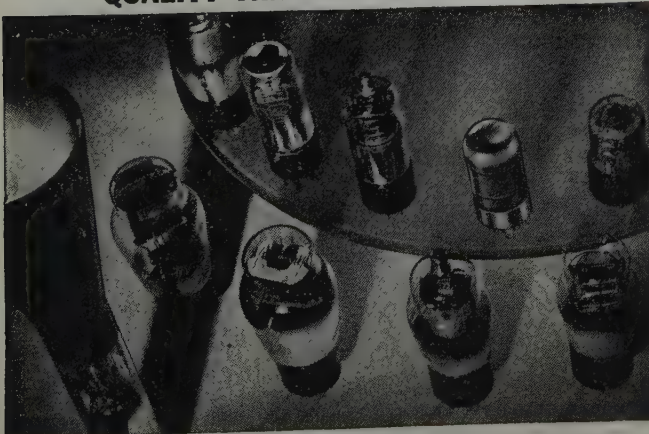
- Technical progress depends upon tireless experiment to perfect performance.

Sylvania circuit engineers are performance perfectionists. They conduct never-ending tests on new circuit and tube combinations using experimental equipment. They constantly improve radio and electronic tube quality. And they compile data that is the raw

material of invention.

This long-range Sylvania research policy, which maintained our standard of quality in peacetime, has proved invaluable in wartime. It has contributed to the improvement of military communications, to the volume production of cathode ray tubes, and to the development of timesaving electronic devices for war industry.

QUALITY THAT SERVES IN WAR



And it will prove no less valuable when victory widens the radio-electronics field. It will contribute to the development of FM radio and practical television. It will help to convert electronic military secrets of today into everyday miracles for better life and work tomorrow.



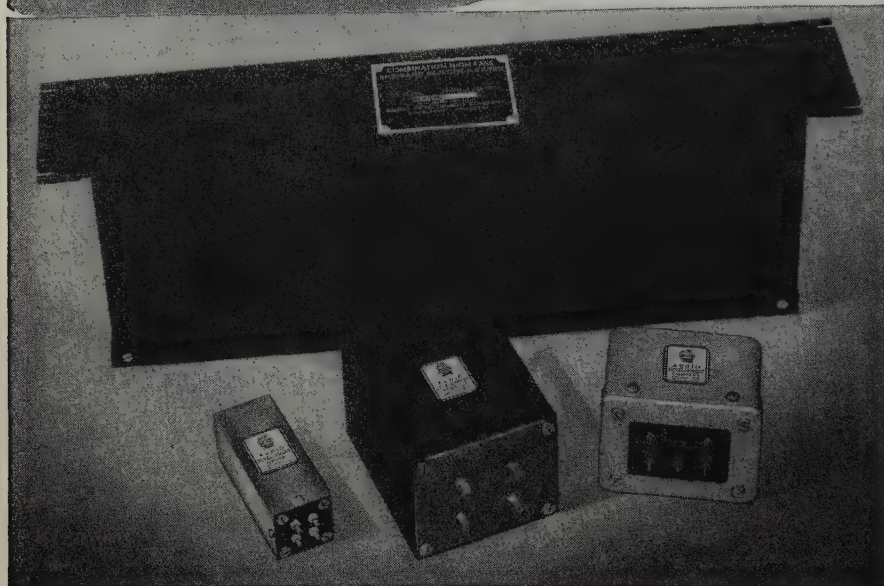
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Audio Development Co.

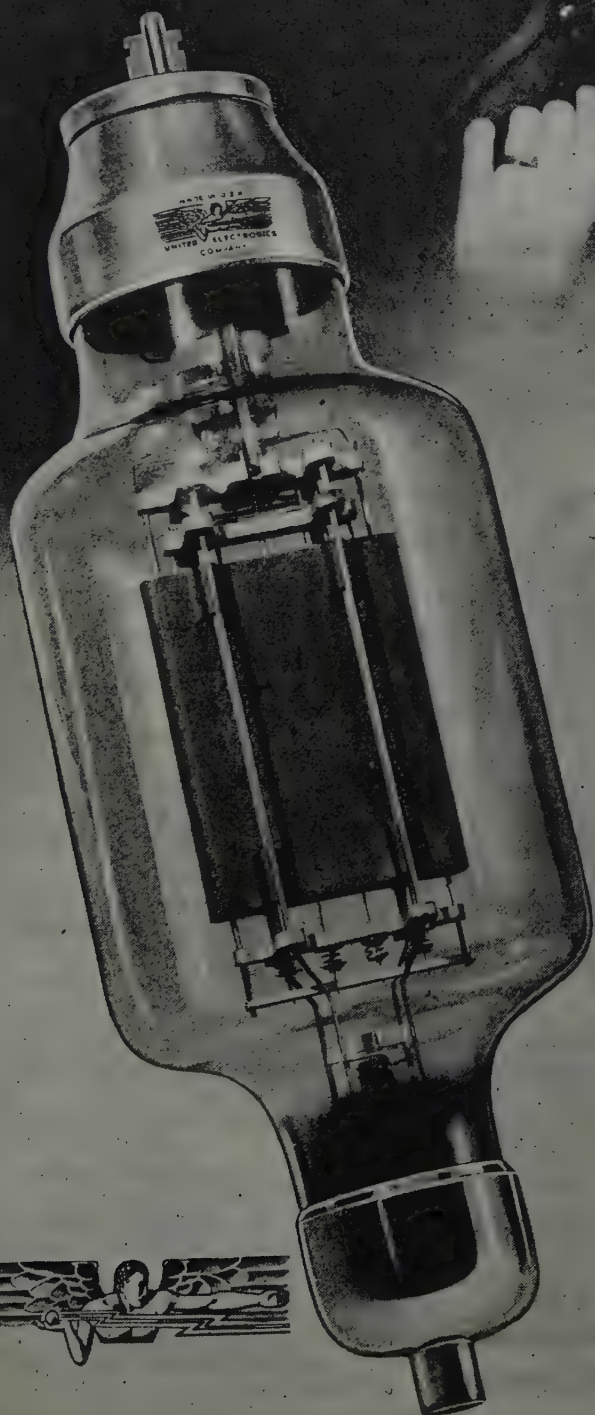
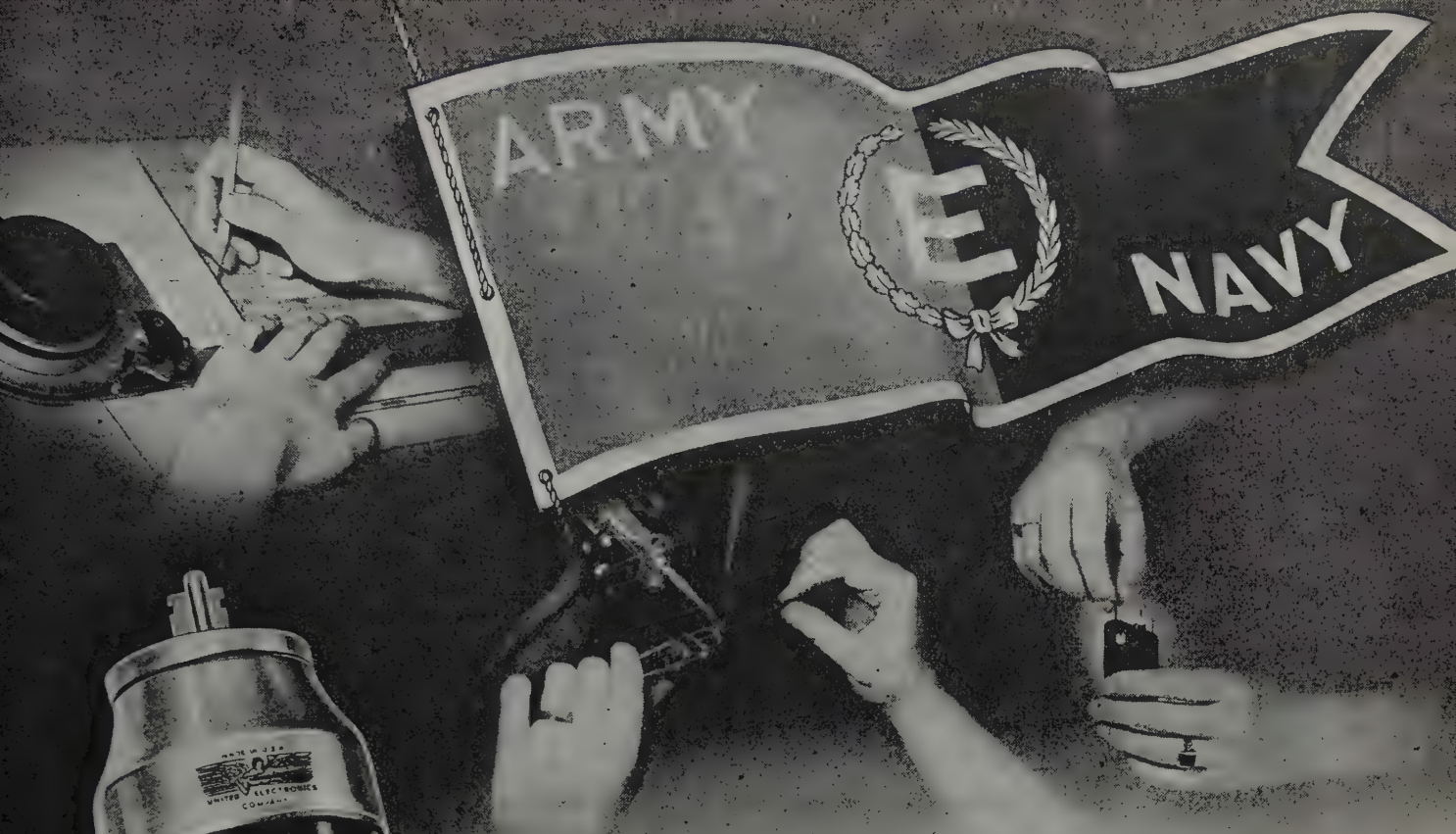
2833 13th Ave. S., Minneapolis, Minn.

Membership

(Continued from page 46A)

- Divins, B., 735 Mace Ave., Bronx, 67, N. Y.
- Dorman, L. R., 226 Tama St., Boone, Iowa
- Dunlap, F. I., 41 C Tom McMillan Homes, Navy Yard, S. C.
- Dunn, S. C., 75 Craggs Ave., Paisley, Renfrewshire, Scotland
- Dutton, O. B., 2705 E. 46 St., Kansas City, Mo.
- Edwards, T. J., Rt. 1, Box 483-O, Ft. Worth, Texas
- Eldridge, H. C., Jr., 227 Oxford Rd., Franklin, Ohio
- Fogg, E. W., 78 Primandine St., Dorchester, 24, Mass.
- Fenyo, T., Casilla de Correo 2783, Buenos Aires, Argentina
- Free, G. O., 3231 Welsberg Dr., 21, St. Louis, Mo.
- Frizen, J. E., APO 825, c/o Postmaster, New Orleans, La.
- Gatton, H. F., 416 Park Ave., Elizabethtown, Ky.
- Gewirtz, H., 224 New York Ave., Brooklyn, N. Y.
- Golembieski, E. H., Ft. George Meade, Md.
- Green, M., 3318 Rodman St., Washington, D. C.
- Haines, B. P., Philco Corp., C and Tioga Sts., Ext. 894, Philadelphia, Pa.
- Hall, E. G., 6131 Locust, Kansas City, Mo.
- Hoffman, E. H., 519 Central Ave., Ardley, Pa.
- Hagaman, B., Rt. 3, Rochester, Minn.
- Hogan, J. F., 78 Hyland Ave., Toronto, Ont., Canada
- Holmbeck, C. H., 829 Everhard, Jackson, Mich.
- Hoyle, W. E., 3831 Rainbow Blvd., Kansas City, Kan.
- Huggins, R. A., San Francisco, Calif.
- Hoyt, C. K., Caledonia St., North Sydney, N.S., Canada
- Isernia, A. R., Cochambamba 1266, Buenos Aires, Argentina
- Joarnski, T., 2633—16 St., N.W., Washington, D. C.
- Kemp, T. H., 20 Highwood Ter., Glen Rock, N. J.
- Kirkpatrick, C. H., 2617 E. 27, Kansas City, Mo.
- Kissler, R. G., 1 Madrona Pl., American Lake Gardens, Tacoma, Wash.
- Kreck, J. A., 915 N. Wayne, Arlington, Va.
- Lee, W. P., WLAK, Lakeland, Fla.
- Littler, R. C., 1400 St. Paris Pike, Springfield, Ohio
- Lounsberry, W. H., 2323 Tower Ave., Superior, Wis.
- McAfee, P. H., Jr., Naval Research Laboratory, Anacostia Station, D. C.
- McCoy, R. T., Radiation Laboratory, M.I.T., Cambridge, Mass.
- Maund, C. A., 2921 Milton, Dallas, 5, Texas
- Menkin, J. I., 524 W. Van Buren St., Chicago, Ill.
- Mebley, M. C., Jr., Box 31, Laurel, Md.
- Meyer, W. H., Canadian General Electric Co., 224 Wallace Ave., Toronto, Ont., Canada
- Montgomery, W. D., 225 E. Fourth St., Rm. 1008, Cincinnati 2, Ohio

(Continued on page 50A)



Our Country Honors
SKILLED HANDS
United for Victory

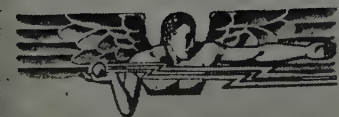
On August 12th, 1943, United Electronics Company received the coveted Army-Navy "E" Award for excellence in production of war materials.

In accepting the honor of flying the "E" burgee over our plant, we extend full and grateful recognition to the skill, the will and the spirit of loyalty which has motivated our personnel ever since Pearl Harbor. To the nation's official tribute we add a hearty "well done" for our family of workers which has achieved an outstanding production record in both quantity and quality of output.

Under the fresh inspiration of our "E" banner, we pledge ourselves to renewed and faithful effort. Our aim continues: more and better electronic tubes . . . for victory today and better living tomorrow.

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ELECTRONICS COMPANY
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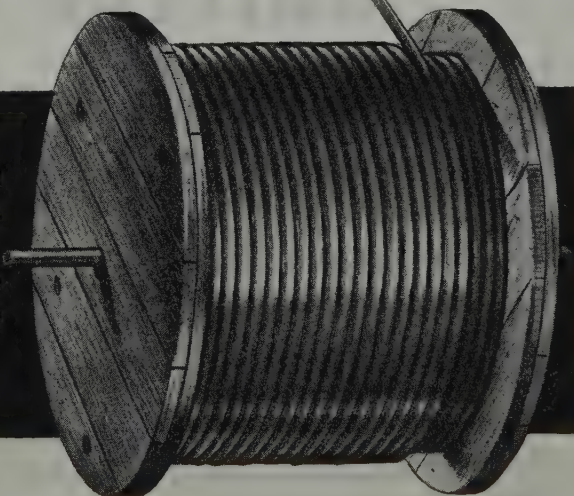
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1/2 YARD - OR 1/2 MILE

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The Andrew glass insulated terminal, an uniquely successful development, may be used with this flexible cable to provide a gas tight system.



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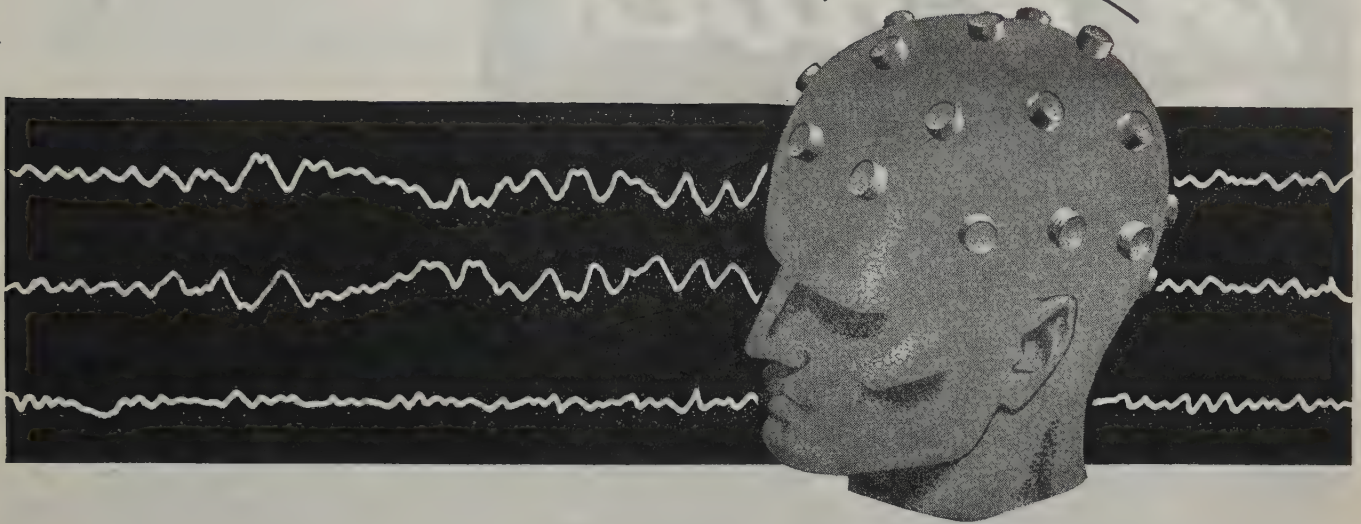
Membership

(Continued from page 48A)

- Moore, N., Legal Division, O.C.S., 4D329 Pentagon Bldg., Washington, D. C.
- Morton, P. L., Electrical Engineering Dept., University of California, Berkeley 4, Calif.
- Naber, J. S., 67 High St., East Haven, Conn.
- Naylor, B. W. P. C., Box 411, Clinton, Ont., Canada
- Norman, F. H., R.F.D., Rockfall, Conn.
- Numez, J., Strangford 5551, Buenos Aires, Argentina
- Oberly, J. J., 100 Brandywine Pl., S.W., Washington 20, D. C.
- Oldmixon, R., 4307-42 St., Sunnyside, L. I., N. Y.
- Olson, R. L., 5109 Indianola Ave., Minneapolis, Minn.
- Paul, W. E., 3835 Main St., Kansas City, Mo.
- Quan, T., 419 West Copper St., Albuquerque, N. M.
- Raybuck, C. B., 4602 Drexel Rd., College Park, Md.
- Robel, R. B., 400 W. Main St., New Prague, Minn.
- Roeder, W. O., 1912 S. 50 Ave., Cicero, Ill.
- Rogers, Y. W., Rt 1, Box 27, Gainesville, Fla.
- Reukauf, D. C., R.F.D. 2, Box 10, Ft. Worth, Texas
- Rosier, H. L., 168 Cabot St., Newton 58, Mass.
- Samuelson, F. L., 311 North Superior, Angola, Ind.
- Saunders, C. T., C.A.P.O. 5 R.C.A.F., Overseas, Newfoundland
- Shackelford, J. W., Box 676, Auckland, New Zealand
- Showalter, E., Jr., 404 W. State St., Marshalltown, Iowa
- Smith, K. C., 128 1/2 Ferrier Ave., Toronto, Ont., Canada
- Smith, Z. R., 1404 E. Broward Blvd., Ft. Lauderdale, Fla.
- Soukup, J. C., 6240 S. Kedzie Ave., Chicago, Ill.
- Sperling, B. R., 295 Westwood Ave., Long Branch, N. J.
- Stone, J. B., 3835 Main St., Kansas City, Mo.
- Stone, J. W., 4939 Adams, Kansas City 3, Kan.
- Upton, L. R., 527 N. Grand Ave., c/o Fox, Theatre, St. Louis, Mo.
- Virgeant, G. H., 1780 Van Dyke, Detroit, Mich.
- Walden, O. A., Rt. 5, Box 169, Dallas, Texas
- Wardale, A. H., 25 Waratah St., Bexley, N.S.W., Australia
- Warren, C. W., 88 Fairview Ave., North Plainfield, N. J.
- Watson, K. M., 1428 D St., S.E., Washington, 3, D. C.
- Welborn, D. L., Wilcox Electric, 14 Chestnut, Kansas City 1, Mo.
- Wilson, L. W., Cl. 13-43 Naval Research Laboratory, Anacostia Station, D. C.
- Young, A. F., 3916 Derry St., Harrisburg, Pa.
- Young, R. D., Rt. 25-A, Kings Park, N. Y.
- Zabel, L. W., 5116 Roseland Pkwy., Mission, Kan.

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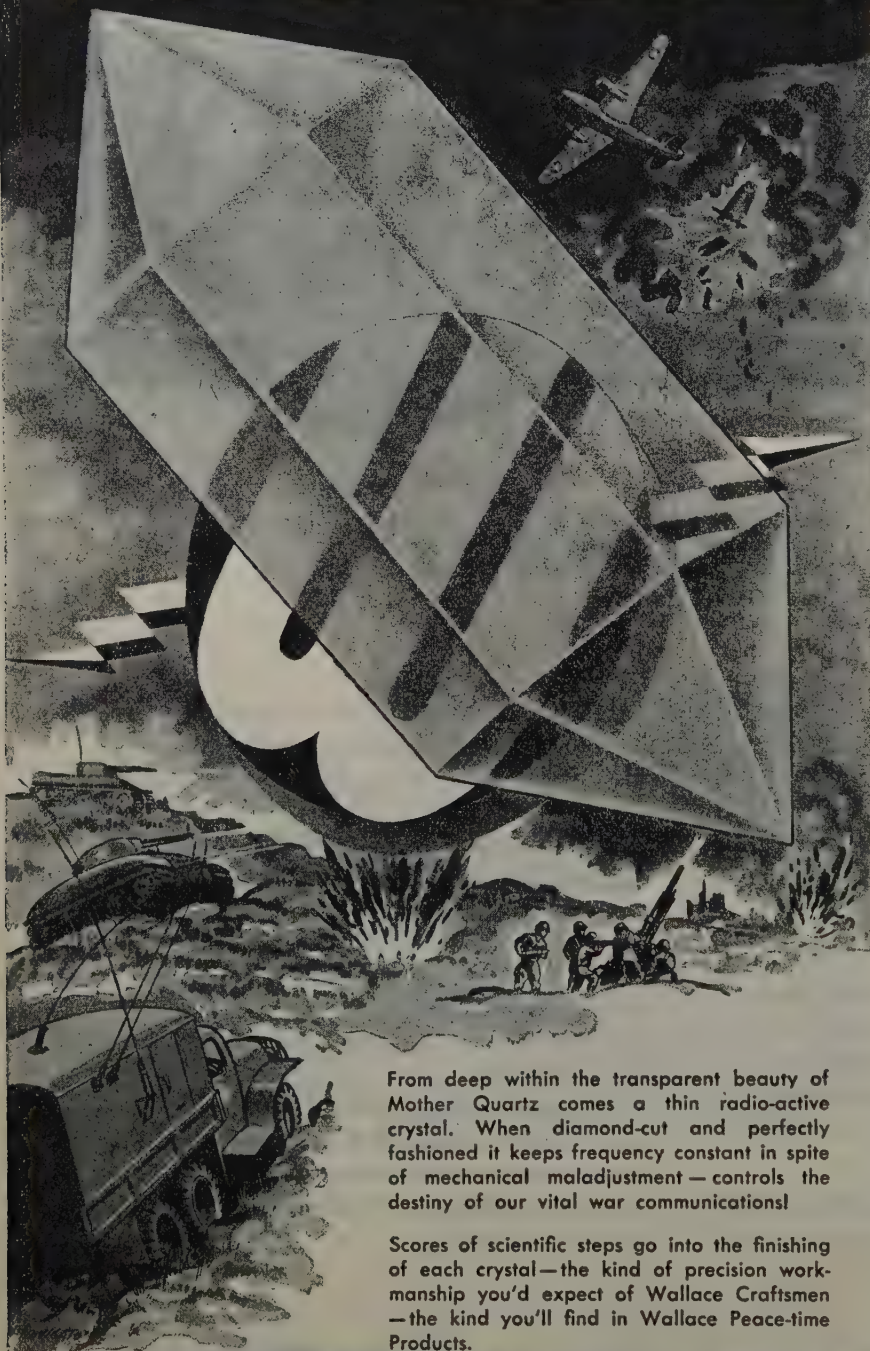
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ATLANTA

"The Use of Radio-Frequency Preheating in the Molding of Plastics," by Scott Helt, Southern Plastics Company; June 18, 1943.

BUFFALO-NIAGARA

"Measurements of Audio Amplifier," by Howard Stephenson, WBEN; September 22, 1943.

CHICAGO

"Mass Production of Quartz Crystals," by Frank Brewster, Galvin Manufacturing Corporation; September 17, 1943.

"Methods and Equipment of Airline Radio Avigation," by L. H. Cameron, Bruce Montgomery, and George Levy, United Air Lines; September 17, 1943.

CINCINNATI

"Engineering Questions and Answers on Plastics," by N. A. Backscheider, Recto Molded Products, Inc.; September 14, 1943.

CLEVELAND

"Frequency Modulation versus Amplitude Modulation at High Frequencies," by Raymond Guy, National Broadcasting Company; June 24, 1943.

INDIANAPOLIS

"The Electron Microscope and Its Applications," by M. C. Banca, RCA Victor Division; September 17, 1943.

KANSAS CITY

"Measuring Velocity of Small Arms-Ammunition by Electronic Methods," by Kirk Phaling, Remington Arms Company, Inc.; September 21, 1943.

"Directional Antennas for Broadcast Stations," by M. W. Woodward, Commercial Radio Equipment Company; September 21, 1943.

PITTSBURGH

Dinner Meeting—Election of Officers for 1943-1944 season, June 14, 1943.

SAN FRANCISCO

"Characteristics of the Ionosphere," by Robert Helliwell, Stanford University; September 1, 1943.

"Propagation of Radio Waves through the Ionosphere," by Karl Spangenberg, Stanford University; September 1, 1943.

"Electronic Applications in the Ship Production Program," by N. E. Porter, Richmond Shipyard No. 1; June 3, 1943.

WASHINGTON

"A Wide-Band Oscilloscope," by E. D. Cook, General Electric Company; June 14, 1943.

"Microwave Electronics," by E. U. Condon, Westinghouse Electric and Manufacturing Company; September 13, 1943.



The following indicated admissions and transfers of membership have been approved by the Admissions Committee. Objections to any of these should reach the Institute office by not later than November 30, 1943

Transfer to Senior Member

Bruck, G. C., 157 S. Harrison St., East Orange, N. J.
Pomeroy, A. F., 82 Mine Mount Rd., Bernardsville, N. J.

Speir, F. H., 324 Rosemary Ave., Ambler, Pa.
(Continued on page 36A)

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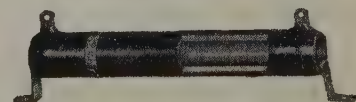


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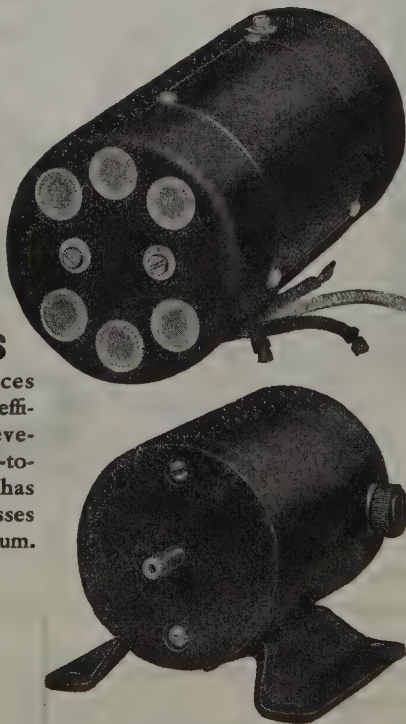
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(Continued from page 34A)

Admission to Senior Member

Clegg, J. E., Torside, St. Andrews Rd., Malvern, Worcs., England

Transfer to Member

Benowitz, H. S., 1301 Seneca Ave., New York, N. Y.
Bliss, A. O., 2585 S. Bayshore Dr., Miami, Fla.
Ruckelshaus, J. G., 110 Pomeroy Rd., Madison, N. J.
Stewart, R. D., No. 10, The Garrison, Barbados, B.W.I.

Admission to Member

Davis, A. C., 1508 W. Verdugo Ave., Burbank, Calif.
Fagen, M. D., 16A Forest St., Cambridge, Mass.
Finke, H. A., 74 Jefferson Rd., Princeton, N. J.
Iannelli, E., 86 Webster Ave., Harrison, N. Y.
Mullin, C. J., Department of Physics, St. Louis University, St. Louis, Mo.
Muniz, R., 7243 Shore Rd., Brooklyn, N. Y.
Nelson, I., 320 Broadway, Bismarck, N. D.
Stanton, A. N., Box 541, Southern Methodist University, Dallas, Texas
Whiting, W. E., 447 Douglas St., Bakersfield, Calif.

The following admissions to Associate were approved by the Board of Directors on October 6, 1943

Adler, H. J., 1205 Sherwin Ave., Chicago, Ill.
Albright, E. L., 163 King George St., Annapolis, Md.
Alsbrook, G. R., 667 Leath St., Memphis, Tenn.
Anderson, D. A., 41 Hopewell Ave., Ottawa, Ont., Canada
Backman, J. A., 902 Broadway, Bend, Ore.
Beck, E. A., 420 W. Michigan Ave., Jackson, Mich.
Becker, H. W., 126 Benson Ave., Vallejo, Calif.
Bellare, D., 1609 W. Sixth St., Brooklyn 23, N. Y.
Beresford, B. P. A., 31 Blyth St., Brunswick, Melbourne, Victoria, Australia
Berlin, L., Hq. Co., A.P.O. 77, c/o Postmaster, Los Angeles, Calif.
Billington, R. M., The Directorate, Posts and Telegraphs Department, Baghdad, Iraq
Bracken, J. F., 25 Lake St., Arlington, Mass.
Brewer, G. R., 135 St. Paul St., Brookline 46, Mass.
Byers, A. C., Radiation Laboratory, Massachusetts Institute of Technology, Cambridge 39, Mass.
Bush, R. R., RCA Laboratories, Princeton, N. J.
Carr, V. R., 1729 Newport Ave., Chicago 13, Ill.
Christiansen, W. G., 328 E. Church Rd., Elkins Park, Philadelphia 17, Pa.
Christophel, G. H., R.F.D. 1, Edwardsburg, Mich.
Claridge, G. C., 11406 S. Edbrooke, Chicago, Ill.
Colen, N. H., 2132 N. Kedzie Blvd., Chicago, Ill.
Coles, K. E., 9153 Boleyn, Detroit, Mich.
Cooke, H. S., Machlett Laboratories, Inc., 25 Grand St., Norwalk, Conn.
Cottingham, H. T., Box 76, Winona, Ont., Canada
Crandall, W. E., U. S. Naval Mine Warfare Test Station, Solomons, Md.
Dabell, H., 386 Broxtowe Lane, Nottingham, England
David, G. B., 812 E. Main St., Lexington 37, Ky.
Davidson, D., 439 Marlboro St., Boston 15, Mass.
Davis, S., 351—99 St., Brooklyn, N. Y.
Davis, W. L., 118 Allenhurst Rd., Buffalo 14, N. Y.
De Glanville, R. G., A.S.E.E., Royal Fort, Bristol 8, England
Duff, G. G., 694 Duquesne St., Montreal, Que., Canada
Dunn, R. F., 501 W. 135 St., New York, N. Y.
Durkovic, J., 2115 S. 18th Ave., Broadview, Ill.
Dusek, J. F., 45—41—39 Pl., Long Island City 4, L. I., N. Y.
Edwards, R. S., 351 Front St., Hempstead, L. I., N. Y.
Evans, W. C. B., 9816 Madison Ave., South Gate, Calif.

(Continued on page 38A)

WITH SWEAT AND TEARS!

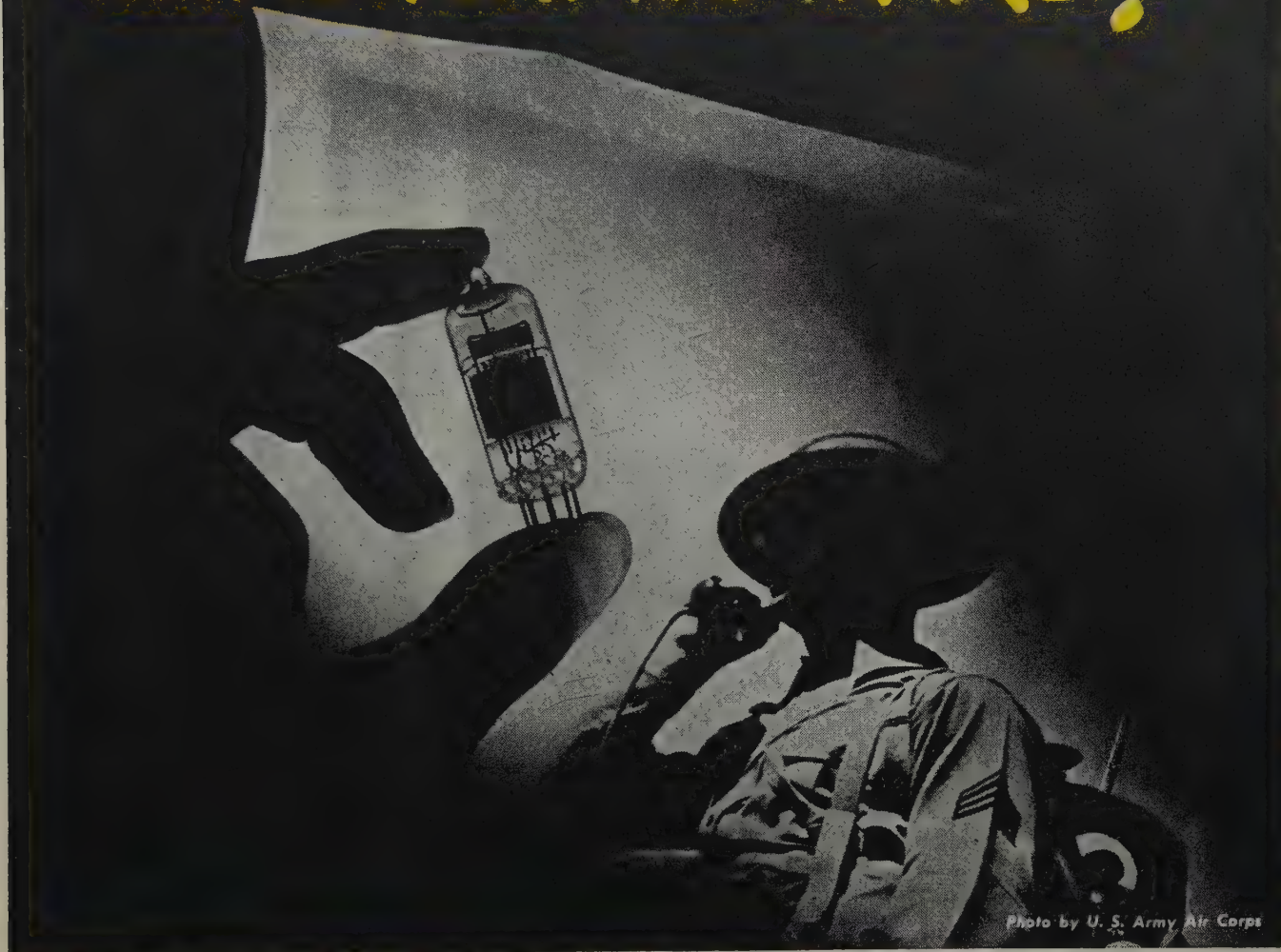


Photo by U. S. Army Air Corps

THE war record of America's radio tube engineers is an impressive one. Yet these able and ingenious men, too, have their "problem children".

In this category are the miniature tubes used by our combat troops in communication radio sets. Admittedly these tubes are tough little "hombres" — especially "tough" for that selected group of engineers whose responsibility is to produce them by the tens of thousands. Only because of the sweat and tears of these men has the flow of miniatures to our armed forces been maintained and steadily expanded month after month.

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- Farmer, J. C., c/o Air Ministry, Tels. 2 (b), 37 Julian Rd., Bristol 9, England
- Filizola, V. F., 5327 Loma Linda St., Los Angeles 27, Calif.
- Fiorilli, N. J., A.P.O. 952, c/o Postmaster, San Francisco, Calif.
- Floegel, M. E., 328 Customhouse, San Francisco, Calif.
- Freezee, W. D., 320 Enos Pl., Hohokus, N. J.
- Friedberg, M. R., 432 Arlington Pl., Chicago 14, Ill.
- Gaillard, R. L., 331 E. 14 St., New York 3, N. Y.
- George, B. C., 22 King Edward Rd., Oxhey, Watford, Herts., England
- Gilbert, J., 566 W. 159 St., New York, N. Y.
- Gilford, S., 2103 Suitland Ter., S.E., Washington, D. C.
- Gillis, F. D., 48 Maywood St., Roxbury, Mass.
- Goddard, R. C., 14 Summit St., East Orange, N. J.
- Goodman, G. H., 919 E. 50 St., Chicago 15, Ill.
- Gorton, G. D., 682 S. Trolo St., Los Angeles, Calif.
- Graves, C. C., 515 Lee St., College Park, Ga.
- Grissom, O., 729 Delaware Ave., Buffalo 9, N. Y.
- Hadley, A. M., 95 Field Rd., Longmeadow, Mass.
- Hamm, H. W., 817 White St., Springfield, Mass.
- Harris, L. F., USMC Air Station, Cherry Point, N. C.
- Hassell, P. A., U. S. Navy Receiving Ship, Building 104, Philadelphia, Pa.
- Herrod, R. A., Jr., General Electric Company, 1635 Broadway, Fort Wayne, Ind.
- Hollingsworth, K. M., Capitol Radio Engineering Institute, 3226—16 St., Washington 10, D. C.
- Hunter, J. H. C., 21 Brook Way, Blackheath, London, S. E. 3, England
- Hunton, W. F., 1227 Linden Ave., Baltimore 17, Md.
- Jaeger, J. H., Bell Telephone Laboratories, 463 West St., New York, N. Y.
- Johnson, C. F., Jr., 48 Roberts St., Watertown, Conn.
- Johnson, P. A., 5453 Nebraska Ave., N.W., Washington, D. C.
- Jones, T. L., 28 Parkland, Kirkwood 22, Mo.
- Lawson, S. A., 4682—24 St., S., Arlington, Va.
- Lord, A. S., 1808 Snyder Ave., Belmar, N. J.
- Loveday, D. W., R.F.D. 6, Portland, Maine
- Mason, V. O., H.M.A.S. Rushcutter, Sydney, N.S.W., Australia
- McGlone, J. M., 5929 N. Paulina St., Chicago, Ill.
- Michon, E., 6907 DeNormanville, Montreal, Que., Canada
- Moats, W. E., Fairburn, Ga.
- Mooers, C. N., Naval Ordnance Laboratory, Washington Navy Yard, Washington, D. C.
- Mushrush, R. S., Jr., 8 State St., Schenectady, N. Y.
- O'Donnell, J. A., 63 Wyneva St., Philadelphia 44, Pa.
- Ostrow, S. M., 1727 Riggs Pl., N.W., Washington 9, D. C.
- Palmer, W. G., Camp Lejeune, New River, N. C.
- Pennini, R. V., 361 South Ave., Whitman, Mass.
- Pudney, L. C., 98 Gudgeheath Lane, Fareham, Hants., England
- Rivman, L. H., 763 Eastern Pkwy., Brooklyn, N. Y.
- Roberts, W. A., 13 Hillbury Rd., London S.W. 17, England
- Royalty, J., Jr., St. Paul Hotel, Dallas 1, Texas
- Ryrie, K. S., 2 St. James Ave., Whetstone, London N. 20, England
- Schumacher, J. H., 4041 N. Kostner Ave., Chicago, Ill.
- Schwarzlose, P. F., 212 E. E. Laboratory, University of Illinois, Urbana, Ill.
- Schwennesen, D., 6827 Loleta Ave., Chicago 30, Ill.
- Seeber, R. G., 3042 N. Troy St., Chicago 13, Ill.
- Sherbin, L. E., 2028 Grand Concourse, New York, N. Y.
- Sherken, J. I., 2813 E. 14 St., Brooklyn, N. Y.
- Shilzony, F. N., Box 2601, Washington 13, D. C.

(Continued on page 42A)



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(Continued from page 38A)

Simmons, S. H., 1421 Olive St., Elkhart, Ind.
 Singh, R., Amar Villa, Civil Lines, Gujranwala, Punjab, India
 Small, F. R., 63 Kendall Ave., Maplewood, N. J.
 Smith, A. H., 4330 Tyler St., Sioux City 20, Iowa
 Stacy, J., 48 Lexington Ave., Bloomfield, N. J.
 Stephanson, E. L., 5151 Cote des Neiges Rd., Montreal, Que., Canada
 Sullivan, V. J., 127 South St., Oyster Bay, L.I., N. Y.
 Sweet, D. H., 189 W. Madison St., Chicago 2, Ill.
 Teeuw, J., 1653—Ninth Ave., San Diego 1, Calif.
 Teomney, G. H., Jr., 88 Hart St., Lynbrook, L. I., N. Y.
 Thompson, Mrs. L., Jr., 526—18 St. S., Arlington, Va.
 Townes, W. D., 708 Wesley St., Petersburg, Va.
 Valladares, J. B., 166—13—33 Ave., Flushing, L. I., N. Y.
 Verton, M. P., A.P.O. 953, c/o Postmaster, San Francisco, Calif.
 Vettel, V. P., 5817 N.E. 14 Ave., Portland 11, Ore.
 Wallin, W., 61 Rivercliff Dr., Devon, Conn.
 Westrate, M. C., 504 N. Parkside Ave., Chicago, Ill.
 Wickes, T. K., 116 Oxford St., Cambridge, Mass.
 Williams, C. E., 6 Acuba Rd., Liverpool 15, England
 Williams, L. C., 124 S. Lafayette Ave., Lexington 23, Ky.
 Winslow, J., 4828 S. Kostner Ave., Chicago 32, Ill.
 Wolbrecht, M. E., 1377 N. Wilton Pl., Hollywood 28, Calif.
 Wolfskill, J. R., 131 Hudson Ave., Red Bank, N. J.
 Yusufzai, A. U. K., Karani Bldg., Victoria Gardens, Bombay, India

Army-Navy "E" Honor Roll

(Continued from page 40A)

Sprague Production Wins Star

For the second time in less than a year, the Sprague Specialties Company of North Adams, Mass. makers of Sprague Capacitors and Koolohm Resistors has won the coveted Army-Navy Production Award. The second award, made to the men and women of the company by Under Secretary of War, Robert P. Patterson on September 25th thus adds the White Star to the Army-Navy Production Award "E" flag originally presented to the company in an impressive ceremony on April 2nd of this year and which was attended by Governor Saltonstall of Massachusetts and high officials of the armed services.

Another RCA Plant Honored

Award of the Army-Navy "E" flag to the Indianapolis plant of the RCA Victor Division of Radio Corporation of America is the fifth such award to be won by RCA.

The RCA plant at Camden, N. J., first flew the Army-Navy "E" flag in January 1942. Since that date three stars, which denote continued excellence in production, had been added.

The Harrison, N. J., plant of RCA Victor won the flag in September 1942, and now has one star.

Radiomarine Corporation of America, awarded the Army-Navy "E" flag in December 1942, has had a star added. The workers of this division also have been presented with the United States Maritime Commission's "M" Pennant and Victory Fleet flag.

The Army-Navy "E" flag was unfurled at RCA Laboratories, Princeton, N. J.



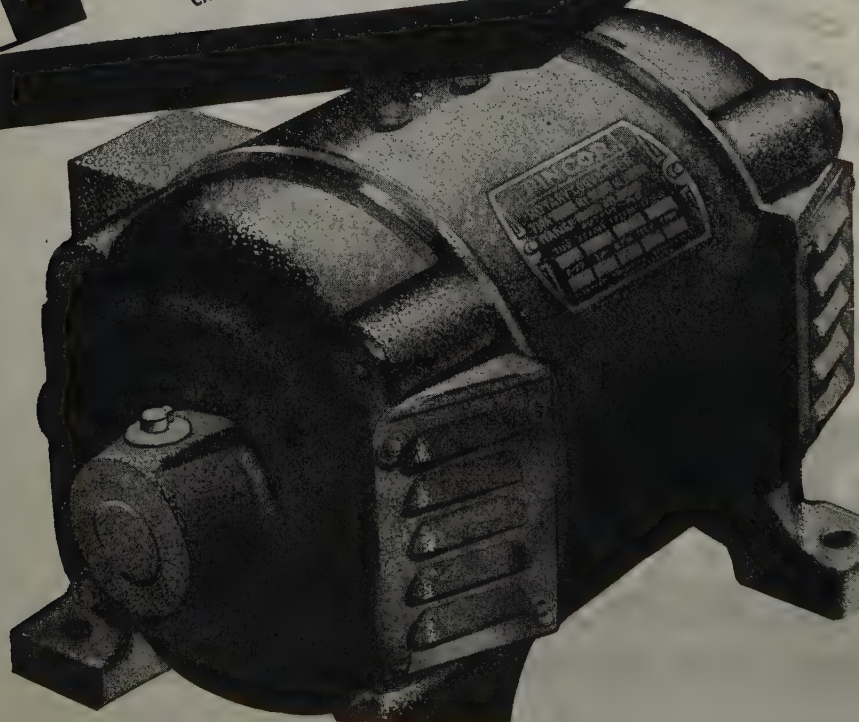
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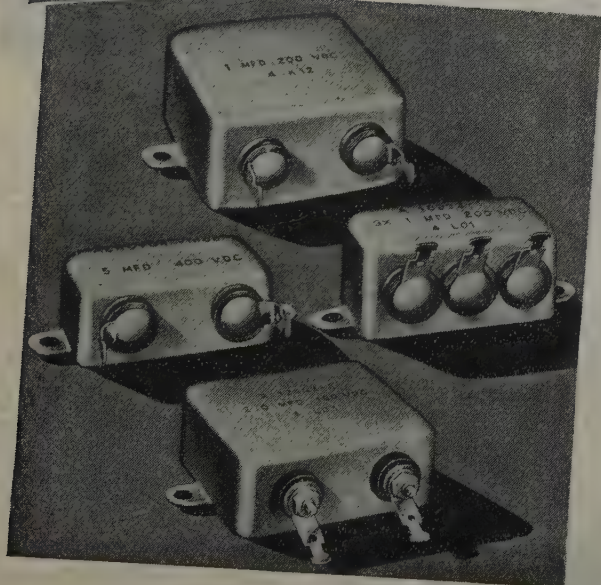
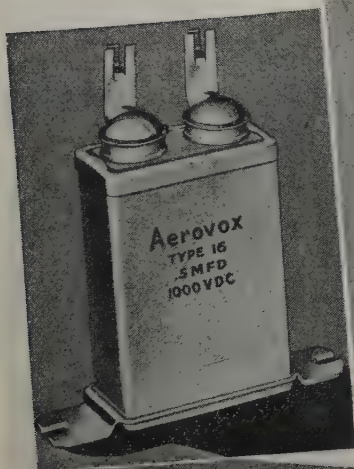
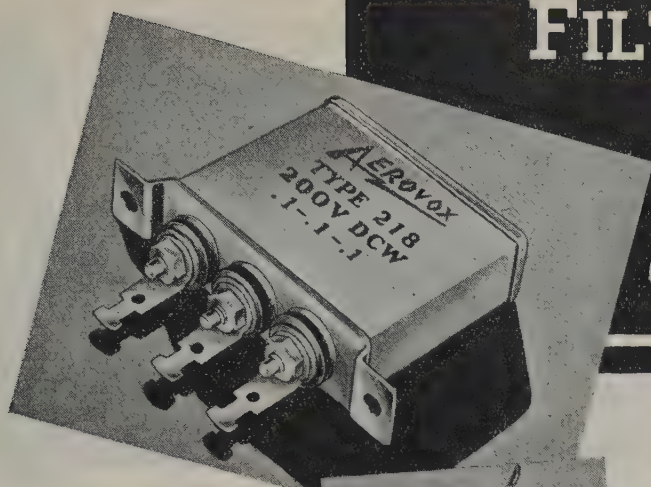
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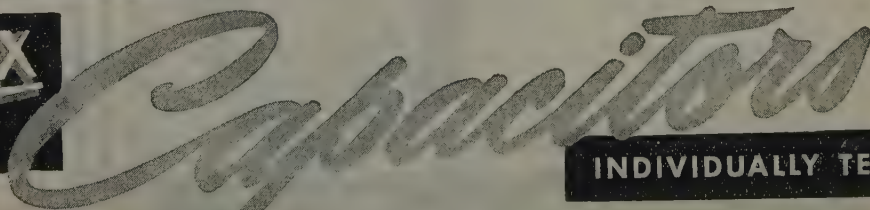
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RADIO TECHNICAL PLANNING BOARD MEMBERS AT NEW YORK, OCTOBER 13

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JOHN A. HUTCHESON

It was announced recently by Dr. L. W. Chubb (M'21-F'40), director of the Westinghouse Research Laboratories, that John A. Hutcheson has been appointed associate director of the laboratories.

Mr. Hutcheson (A'28-M'30), for the last three years has been manager of engineering at the Baltimore radio division of the West-

inghouse Electric and Manufacturing Company. In that post he directed a large staff of engineers developing new types of radio equipment for the armed forces and designing secret electronic devices for military use. His immediate assignment at the laboratories will be to direct wartime microwave research but his scope of responsibility will include all phases of research engineering, Dr. Chubb said.



JOHN A. HUTCHESON

Soon after he received his Bachelor of Science degree in electrical engineering at North Dakota in 1926, Mr. Hutcheson joined Westinghouse as a graduate student and was assigned to radio engineering work. He has been in the radio engineering department of the Company ever since, first at East Pittsburgh, Pennsylvania, then at East Springfield, Massachusetts, and finally at Baltimore. He was named engineering manager at Baltimore in 1940.

In the early thirties, he helped design the world's most powerful broadcast transmitter at radio station WLW in Cincinnati, Ohio, and was in charge of Westinghouse television development from 1938 until the war temporarily postponed that work. He also directed engineering for the Westinghouse X-ray division at Baltimore during the last year.

In 1939 he was appointed to the National Television Standards Committee by the Federal Communications Division to study television broadcasting and receiving and to prepare recommendations for standards throughout the industry. He is serving the National Defense Research Committee as a member of the division which is doing advanced electronics work under direction of

(Continued on page 36A)

BLILEY CRYSTALS

RIDE WITH THE SCR-299

Built by **hallicrafters**

ONE of the outstanding achievements in wartime radio transmitter design is the SCR-299. Serving equally well as a mobile or stationary radio station, this now famous equipment is doing a real job on our battle fronts.

This war is run by radio. The vital importance of maintaining reliable communications necessitates the selection of quartz crystal units that are accurate and dependable. Bliley Crystals are engineered for service they are used in all branches of military communications and are, of course, supplied for the SCR-299.

BACK THE ATTACK WITH WAR BONDS

BLILEY ELECTRIC CO., ERIE, PA.

FOR SAFETY'S SAKE



IRC TYPE MP RESISTORS

Keeping America's newest broadcasting FM and television transmitters operating with a minimum of interruption or distortion is a challenging job. There's no room for chance with thousands of dollars of air-time and talent services at stake. To make certain that transmitters and control instruments will function perfectly under their full power loads—often running to 50 kilowatts—daily tune-up tests at off-time periods have become standard practice. But to throw this unbridled wattage out over the regular antenna could conceivably cause air-signal havoc . . . squeals . . . crashes . . . shot noises.

So, one of the early FM and television problems faced by broadcast engineers was the development of a dummy antenna simulating the high frequency characteristics of the regular antenna,

in order to obtain informative and accurate check-readings.

ANOTHER IRC APPLICATION

IRC's MP Resistors, when water-cooled, furnished the ideal solution. These sturdy units embody all the required features while readily dissipating the tremendous heat factors involved.

Tests indicate that water-cooling at tap pressure increases their rating by as much as 90 times.

If resistances will play a part in your post-war products, consult IRC. You'll obtain unbiased engineering counsel, for IRC makes more types of resistors in more shapes for more applications than any other manufacturer in the world.



Proudly we fly the Army-Navy E flag with two white stars . . . symbol of maintained excellence in production of war materiel.

INTERNATIONAL RESISTANCE COMPANY

401 N. Broad Street • Philadelphia 8, Pa.



1,001 USES

Condensed Power for Years of Service

VERSATILITY and dependability were paramount when *Alliance* designed these efficient motors — *Multum in Parvo!* . . . They are ideal for operating fans, movie projectors, light home appliances, toys, switches, motion displays, control systems and many other applications . . . providing economical condensed power for years of service.

Alliance Precision

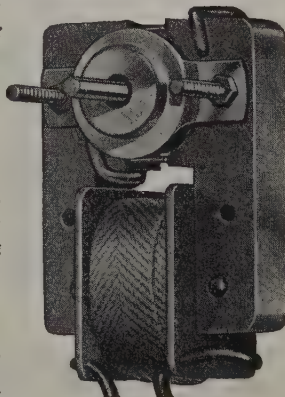
Our long established standards of precision manufacturing from highest grade materials are strictly adhered to in these models to insure long life without breakdowns.

EFFICIENT

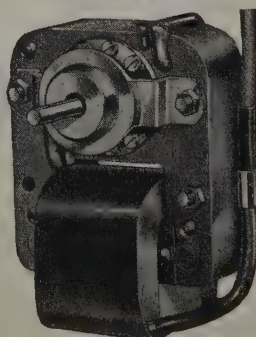
Both the new Model "K" Motor and the Model "MS" are the shaded pole induction type — the last word in efficient small motor design. They can be produced in all standard voltages and frequencies with actual measured power outputs ranging upwards to 1/100 H. P. . . Alliance motors also can be furnished, in quantity, with variations to adapt them to specific applications.

DEPENDABLE

Both these models uphold the *Alliance* reputation for all 'round dependability. In the busy post-war period, there will be many "spots" where these Miniature Power Plants will fit requirements . . . Write now for further information.



Model "MS" — Full Size
Motor Measures
1 3/4" x 2 x 3 1/8"



New Model "K" — Full Size
Motor Measures
2 1/8" x 2 3/8" x 3 1/4"

Remember Alliance!
—YOUR ALLY IN WAR AS IN PEACE

A
ALLIANCE
MANUFACTURING CO.
ALLIANCE . OHIO

I.R.E. People

(Continued from page 34A)

Dr. Karl T. Compton, president of the Massachusetts Institute of Technology. He is also a member of a special advisory committee appointed by Secretary of War Stimson for research and development on war equipment.

Earlier this year he received an honorary doctor's degree from the University of North Dakota in recognition of his achievements in radio and electronics engineering.

C. A. PRIEST

C. A. Priest (A'24-M'38) has been appointed manager of the transmitter division of the General Electric electronics department, Dr. W. R. G. Baker (A'19-F'26), vice president in charge of the department, has announced. In this capacity, Mr. Priest will assume the responsibility for the operations of the Syracuse, New York, plant of the division, and will have his headquarters in that city. Mr. Priest was engineer of the radio transmitter engineering Division at Schenectady, New York, before his new appointment.



C. A. PRIEST

Mr. Priest was born in Solon, Maine, and was graduated from the University of Maine in 1922 with the degree of B.S. in electrical engineering. Three years later, he received his E.E. degree. He entered the testing department of the General Electric Company in Schenectady in June, 1922, and in August of the same year was assigned to the transmitter section of the radio department where he has been since, with the exception of the period from August, 1927, to May, 1928, when he was sent to Japan as an employee of the International General Electric Company. While in Japan, he was engaged as a sales engineer on radio apparatus. In May, 1928, Mr. Priest returned to the United States and to the General Electric radio department, where he became particularly active in the high-power work of the transmitter section.

Mr. Priest was named designing engineer of radio transmitters in January of 1930, and in July, 1938, became engineer in charge of the radio transmitter engineering division.

(Continued on page 38A)



When Sandino was a rebel

Henry L. Stimson had personally arranged a truce between the two factions in Nicaragua, and the Marines were asked to stay until after the 1928 election.

But one young "general" refused to be bound by the truce, and fled with his little band into the wilds of the department of Neuva Segovia. There Augustino Sandino proclaimed himself head of a republic, and might have lived unmolested to a ripe old age if he hadn't taken up the practice of ambushing small detachments of Marines.

After 400 of Sandino's men surrounded 39 Marines near Ocotal, killing one and wounding one before they were driven off, Heintz and Kaufman Ltd. received an urgent message from Washington to design and build at the earliest moment 22 special field transmitters capable of being transported along narrow jungle trails, and of being operated even after immersion in water.

This was the first time Heintz and Kaufman equipment served with the Marines. Today as thousands of Gammatron tubes pass final inspection, we like to think that some will see action with the U. S. Marine Corps . . . confident that every Gammatron will have that extra stamina, efficiency, and dependability when the odds are long that the Marines themselves possess.

HEINTZ AND KAUFMAN LTD.

SOUTH SAN FRANCISCO • CALIFORNIA, U. S. A.



Gammatron Tubes

HK-854 . . This general purpose Gammatron triode offers exceptional VHF performance, and has the ability to withstand high voltages. Maximum plate dissipation 450 watts.

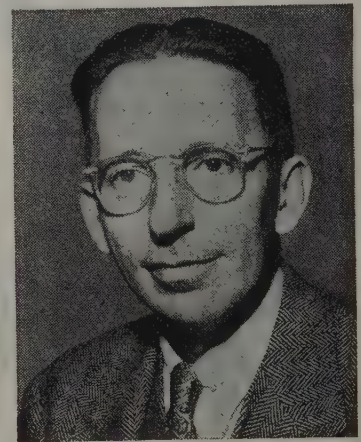
I.R.E. People

(Continued from page 36A)

R. H. SIEMENS

R. H. Siemens (A'41) has been appointed chief engineer of RCA Victor Argentina, wholly-owned RCA subsidiary company in Buenos Aires, it was announced on October 28, 1943, by J. D. Cook, managing director of RCA Victor's International Division. He succeeds Paul Bennett, who has returned to Camden headquarters.

Siemens joined RCA in 1933, as a vacuum-tube application engineer at the Company's Harrison, New Jersey, engineering laboratories, and four years later he was assigned to field work in Chicago. In 1938, he was transferred to Camden as engineer in charge of the design and development of a complete line of small radio receivers.



R. H. SIEMENS

When the manufacture of these sets was centralized at the Company's new Bloomington, Indiana, plant, Siemens also went there as development engineer. While there he also gained further experience in the design, development, and production engineering of radio transmitters, radio receivers, and specialized equipment for the United States armed forces. Later he was assigned to RCA's Government Equipment Section at Camden. Here he handled research contracts with all divisions of the United States armed forces and with the Office of Scientific Research and Development.

His present assignment is not his first experience in South America. In 1939, he designed and installed two 400-watt short wave transmitting stations in Bogota, Colombia. At the time he also developed all-wave radio receivers that found wide acceptance in Colombia, and short-wave radio link circuits for intercommunication of a long-distance radio system in Bogota.

Prior to joining RCA, Mr. Siemens was chief engineer of the ICA Export Corporation where he produced long and short-wave receivers for the South American and European markets. He was also a development engineer for the Fada Company, and owner of Radio Construction Laboratories, in New York, which specialized in the development of custom-built receivers and battery eliminators. Mr. Siemens holds Bachelor of Science and Electrical Engineering degrees from Cooper Union University, in New York City.

Proceedings of the I.R.E. December, 1943



WINNING THE WAR
ON EVERY
BATTLEFRONT
IN THE
hallicrafters
SCR-299
COMMUNICATIONS
TRUCK

PAPER, OIL AND ELECTROLYTIC CAPACITORS

**INDUSTRIAL
CONDENSER
CORPORATION**

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DISTRICT OFFICES IN PRINCIPAL CITIES
QUICK DELIVERY FROM DISTRIBUTOR'S STOCKS



to lift another mist from the mind of man

War's necessity mothers tomorrow's blessing. War-born electronic devices which now strengthen and sharpen a war pilot's radio signal may, some happier tomorrow, guard the glory of a symphony.

Who knows the future of these discoveries which keep our pilots in clear communication, even through the deafening crackle of a tropical storm? Who knows what undreamed comforts, undreamed

glories flicker in the electronic tubes? Or in any of the modern miracles so familiar to us at Sylvania?

New sound for the ears of the world. New knowledge for the eyes of the world. More mists of ignorance swept away! Those are the potentials which inspire us, in everything we do, to work to one standard and that the highest known.

SYLVANIA ELECTRIC PRODUCTS INC.

EXECUTIVE OFFICES: 500 FIFTH AVENUE, NEW YORK 18, N. Y.

RADIO TUBES, CATHODE RAY TUBES, ELECTRONIC DEVICES, INCANDESCENT LAMPS, FLUORESCENT LAMPS, FIXTURES AND ACCESSORIES

IN ACTION ON THE HOME FRONT . . . Sylvania Fluorescent Lamps and Equipment are helping our war factories speed production. Sylvania Radio Tubes are helping bring information and entertainment to homes throughout the land. Sylvania Incandescent Lamps are serving long and economically in these same homes. As always, the Sylvania trade-mark means extra performance, extra worth.



ADC

Filters and Transformers ...for Unusual Jobs



Where Performance Comes First!

The built-in performance standards of ADC Filters and Transformers represent the culmination of years in the design and manufacture of specialized communications equipment. These years of scientific development account in large measure for the tangible values that assure ADC dependability and outstanding operating efficiency. Perhaps this background of practical transformer experience can be of help to you in solving a critical design or production problem.

In addition to filters and transformers, Audio Development Company manufactures an extensive line of specialized communication components — reactors, equalizers, key switches, jacks, jack panels, plugs, etc.



Audio Development Co.

2833 13th Ave. S., Minneapolis, Minn.



BUFFALO-NIAGARA

"Present-Day Direct Recording on Wire and Disk" by Richard Blinzler, Buffalo Broadcasting Corporation; October 20, 1943.

CLEVELAND

"Radio Installations in the Amazon River Valley," by R. A. Fox, WGAR Broadcasting Company; September 23, 1943.

CINCINNATI

"Recent Improvements in Phonograph Reproduction," by J. D. Reid, Crosley Corporation; October 12, 1943.

CONNECTICUT VALLEY

"A New Electron Microscope," by Igor Bensin, General Electric Company; September 13, 1943.

"The Theory and Application of Industrial Heating," by J. P. Jordan, General Electric Company; October 15, 1943.

DALLAS-FORT WORTH

Sound Pictures, "Television," from General Electric Company; "The Jap Zero," and "Mission Accomplished," from the Army Air Corps; October 15, 1943.

DETROIT

"Electronics at Work," by Carl Madsen, Westinghouse Electric and Manufacturing Company; September 17, 1943.

EMPORIUM

"You Can Teach an Old Dog New Tricks," by Robert Manhardt, Sylvania Electric Products, Inc.; October 9, 1943.

Election of Officers, October 9, 1943.

INDIANAPOLIS

"Personnel Planning for the Post War," by F. H. Kirkpatrick, Radio Corporation of America; October 15, 1943.

"Engineering News Reviews" (illustrated), by H. I. Mertz, Vice Chairman; October 15, 1943.

KANSAS CITY

"Methods Used to Effect Mass Production of Quartz Crystals," by M. E. Hall, Jr., Universal Television Company, Inc.; October 19, 1943.

"Use of Supersonic Frequencies in Materiel Inspection," by Boley Andrews, The Vendo Company; October 19, 1943.

LOS ANGELES

"Design and Production of High-Q Audio Reactors," by C. A. Campbell, Attic-Lansing Corporation; September 21, 1943.

NEW YORK

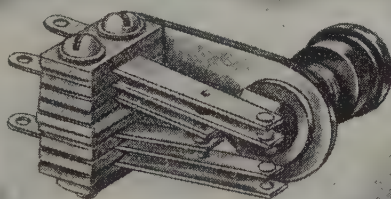
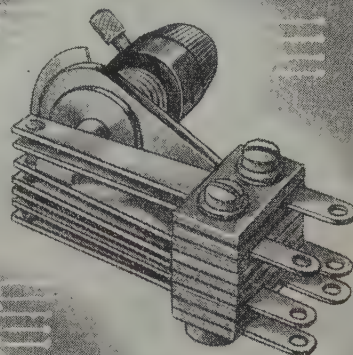
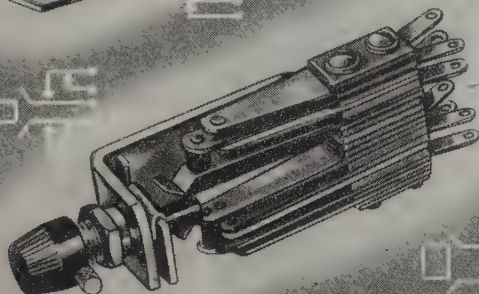
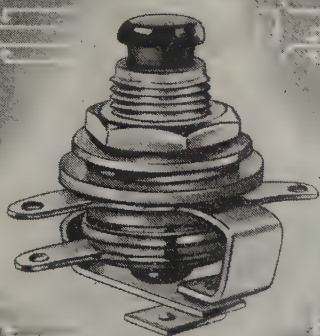
"Application of Electronics to Medical Science," by D. H. More, College of Physicians and Surgeons of Columbia University; October 6, 1943.

"Need for an Instrument to Measure pH in Localized Areas of the Mouth," by Bernard Thomas School of Dental and Oral Surgery of Columbia University; October 6, 1943.

"An Amplifier For Low-Level Photoelectric Currents," by J. L. Nickerson, Department of Physiology of Columbia University; October 6, 1943.

"Electronic Apparatus For Recording Electric Potentials in Nerves and Muscles" (with demonstrations), W. M. Rogers, Department of Anatomy of Columbia University; October 6, 1943.

(Continued on page 42A)



FOR TOP EFFICIENCY AT THE KEY-POINT IN A CIRCUIT **UTAH SWITCHES** EVERY TIME!

Where the human element and mechanical perfection must combine to provide top performance, insist on Utah Switches. They are time-tested in hundreds of electrical applications in industrial plants and on far-flung battle-fronts.

There's a Utah Switch for virtually every circuit

UTAH Switches are made to fit your electrical and space requirements. Compact size, highest quality material and precision manufacture make Utah Switches everything a switch should be. Utah "Imp" push-button switches have the finest nickel silver or phosphorus bronze springs with integral contacts. Springs are fully insulated from the mounting bushing. High-grade phenolic insulation is used. They

are available in three circuit arrangements: "single make," "single break," one "break make."

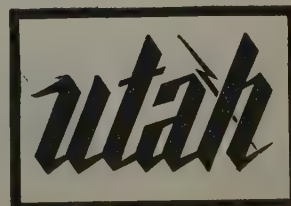
Also available are Utah Rotary and push-button jack switches, in long and short types. Small and compact in size, they are made to take minimum panel space. Full insulation is provided for all electrical parts.

Take advantage of Utah's extensive electrical and electronic experience. Write today for full information on Utah switches.

UTAH RADIO PRODUCTS COMPANY, 842 Orleans St., Chicago, Ill. Canadian Office: 560 King St. West, Toronto. In Argentina: UCOA Radio Products Co., S. R. L., Buenos Aires. Cable Address: UTARADIO, Chicago.

**PARTS FOR RADIO, ELECTRICAL AND ELECTRONIC DEVICES, INCLUDING
SPEAKERS, TRANSFORMERS, VIBRATORS, VITREOUS ENAMELED RESISTORS,
WIREWOUND CONTROLS, PLUGS, JACKS, SWITCHES, ELECTRIC MOTORS**

CABLE ADDRESS: UTARADIO, CHICAGO





The New Genie in a Bottle

Arabian Nights' analogies are left far behind when we talk about the future possibilities of electronic energy in thin glass tubes: the twentieth century genie in a bottle. An incredibly sensitive and positive control of industrial processes is now possible, and every industry must face the probability of technical revolution.

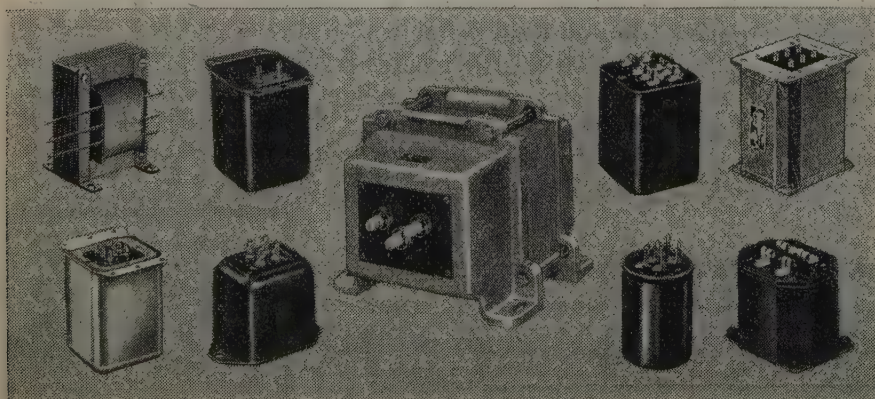
Back of the electron tube, energizing it, is the transformer. Both in war and in peace this mechanism is the special concern of Stancor engineers. Many improvements developed and tested in war, and new developments planned for peace, will emerge from the Stancor laboratory to contribute to post-war industry.



STANCOR

STANDARD TRANSFORMER CORPORATION
1500 NORTH HALSTED STREET · CHICAGO

Manufacturers of quality transformers, reactors, rectifiers, power packs and allied products for the electronic industries.



(Continued from page 40A)

"Electronic Energy Analyses in Psycho-Physiological Research," by John Lynn and Charles Scheer, Department of Neurology of Columbia University; October 6, 1943.

PHILADELPHIA

"RCA Laboratories at Princeton," by E. W. Engstrom, RCA Laboratories; October 7, 1943.

PITTSBURGH

"The Production of the Radio Program; Adventures in Research," by Phillips Thomas, Westinghouse Electric and Manufacturing Company; October 4, 1943.

PORTLAND

"Design of Antenna Tuning Networks," by V. J. Andrew, Victor J. Andrew Company; August 25, 1943.

ST. LOUIS

"Communications in Civilian Defense," by O. S. McDaniel, United States Army; October 1, 1943.



The following indicated admissions and transfers of membership have been approved by the Admissions Committee. Objections to any of these should reach the Institute office by not later than December 31, 1943.

Transfer to Senior Member

Atkins, C. E., 1100 Oak Ave., Evanston, Ill.
Brauer, H. H., 76 East Boulevard, Rochester, N. Y.
James, V. N., 2841 Dyer St., University Park, Dallas, Texas
Martin, H. B., Radiomarine Corporation of America, 75 Varick St., New York, N. Y.
Persons, C. B., 1559-19 St., North, Arlington, Va.
Samuel, A. L., Bell Telephone Laboratories, 463 West St., New York, N. Y.
Sharpe, M. O., 135 North Park Dr., Arlington, Va.
Town, G. R., 148 Colebourne Rd., Rochester, N. Y.

Admission to Senior Member

Attwood, S.S., Room 277, W. Engineering Bldg., Ann Arbor, Mich.
Riblet, H. B., 93-18 Lamont Ave., Elmhurst, L. I., N. Y.

Transfer to Member

Alverson, J. G., 3438 Niolopua Dr., Honolulu, T. H.
Ashton, J. O., Hurl Towers Apts., Greenwich, Conn.
Buckingham, E., 3006 Gough St., San Francisco, Calif.
Harrison, C. W., Jr., Cruft Laboratory, Harvard University, Cambridge, Mass.
Hidy, J. H., 365 Stewart Ave., A-24, Garden City, L. I., N. Y.

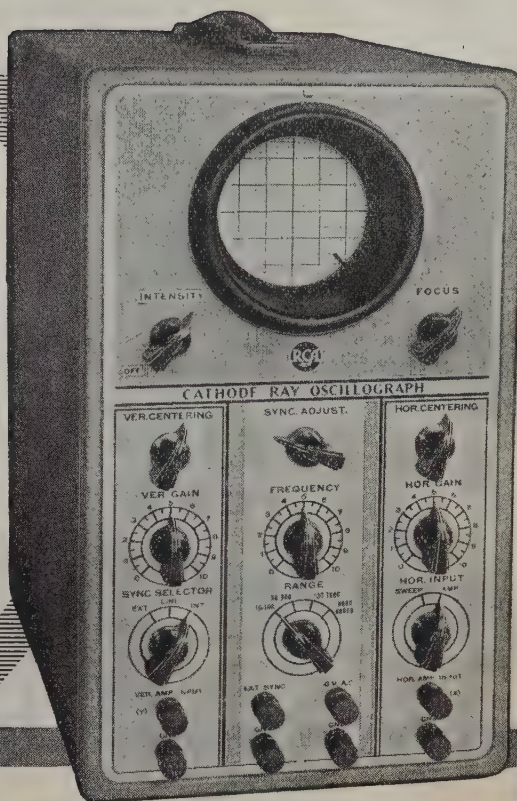
The following admissions and transfers were approved by the Board of Directors on November 3, 1943.

Admission to Senior Member

Barker, P. L., Grafton Hotel, Connecticut Ave., Washington, D. C.

(Continued on page 44A)

The New RCA 3-INCH CATHODE RAY OSCILLOSCOPE No. 155-C



10 TO 60,000 CYCLES!

New improved timing axis oscillator provides extraordinarily wide range—10 to 60,000 cycles—never before available in a 3-inch 'scope.

EXTRA-BRILLIANT IMAGE!

New built-in, deep, light-shield makes image appear surprisingly brilliant—even in bright daylight. Screen is quickly removable—easily changed.

DIRECT DEFLECTOR PLATE CONNECTION!

A special side opening in case is provided for direct deflector plate connection—facilitating use of tube for the higher frequencies.

NEW RCA UNIVERSAL BINDING JACK!

Extremely handy. A combination binding post and pin jack for universal application. Permits quick, positive connection with any type lead terminals. An exclusive RCA feature.

3-INCH CATHODE RAY TUBE!

Three-inch cathode ray tube assures adequately detailed image for practically all applications.

VERSATILE, PORTABLE, FOR LABORATORY AND SERVICE WORK!

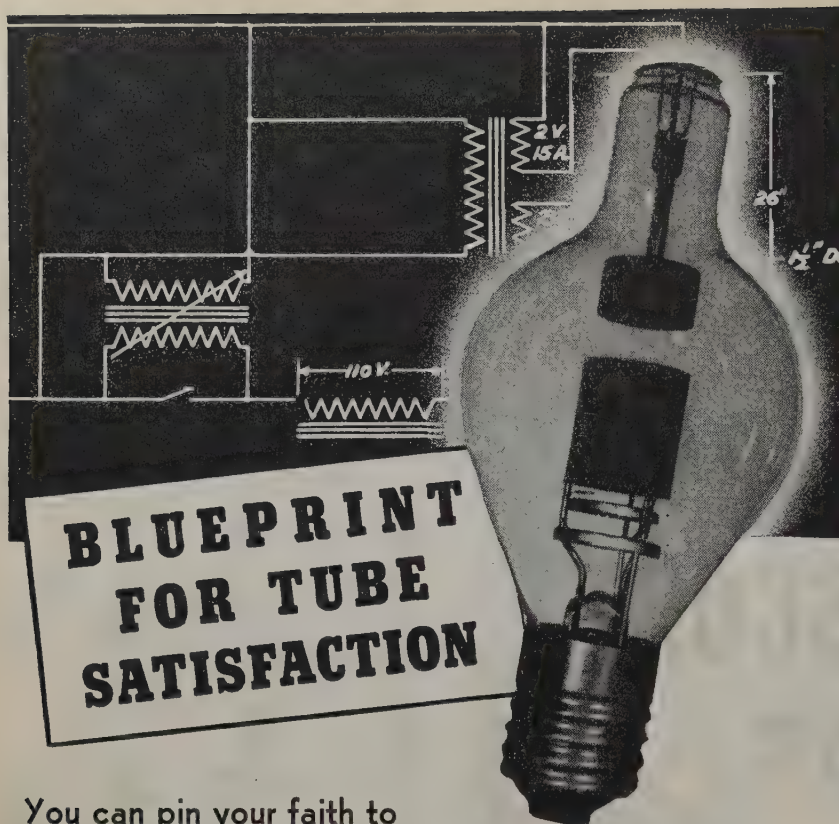
Especially intended for the better class service engineers. For field service, industrial testing, and general commercial and laboratory work.

Rugged enough to withstand every-day field and service usage, yet built throughout to exacting laboratory standards, this RCA 155-C 3-Inch Cathode Ray Oscilloscope is particularly recommended for all-purpose requirements. Note its unusual features, briefly described on this page. Write for special RCA Bulletin containing complete information about this fine instrument. Address Test Equipment Section 44H, RCA Victor Division, Radio Corp. of America, Camden, N. J.



RCA TEST AND MEASURING EQUIPMENT





You can pin your faith to

— CETRON —

"The tubes that engineers enthuse about"

Phototubes

Use by the leading manufacturers . . . wherever phototubes of the utmost efficiency and dependability are needed.

Rectifiers

Cetron Rectifiers are famous for their sturdy construction, and constant, high-efficiency, long-life service.

Electronic and special tubes

Used and praised by the leading manufacturers in the industry. Naturally, Cetron creates and produces all kinds of special tubes for special purposes and if you have a problem along this line, we invite you to consult with our experienced engineers.

Prompt Deliveries on most types.



CONTINENTAL ELECTRIC COMPANY

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NEW YORK OFFICE
263 W. 14th ST.



(Continued from page 42A)

Levy, S. J., 600 Fourth Ave., Bradley Beach, N. J.
McCreary, H. J., 320 Lewis Ave., Lombard, Ill.
Moore, J. R., Box 12, Dutch Neck, N. J.
Ryder, R. M., Bell Telephone Laboratories, Murray Hill, N. J.

Transfer to Senior Member

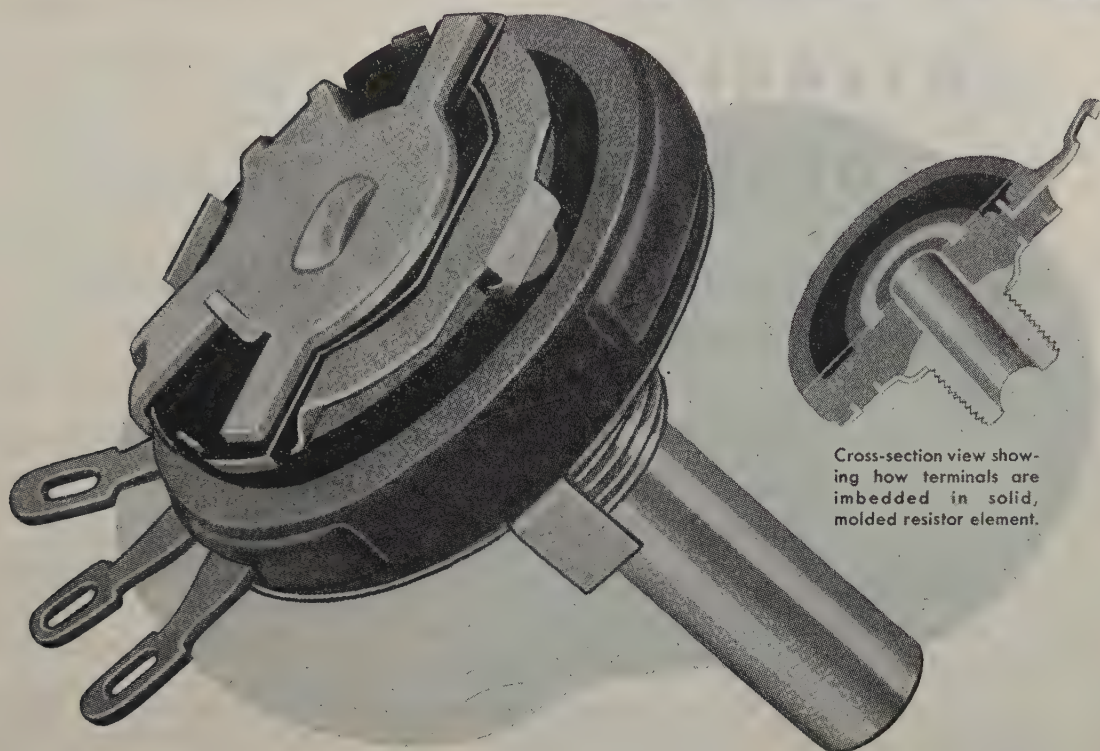
Breazeale, W. M., Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.
Bronwell, A. B., Northwestern University, Evanston, Ill.
Chipp, R. D., 4805—14 St., N.W., Washington D. C.
Epstein, D. W., RCA Laboratories, Princeton, N. J.
Gibson, W. T., Lopen House, Seavington, Somerset, England
Hector, L. G., 57 State St., Newark, N. J.
Hunt, A. B., Box 369, Montreal, Que., Canada
Jenks, D. W., Electronic Tube Engineering Division, General Electric Company, Schenectady, N. Y.
King, R. W., Cruft Laboratory, Cambridge, Mass.
Lidbury, F. A., Box 346, Niagara Falls, N. Y.
Nicol, F. H., RCA Laboratories, Princeton, N. J.
Paddon, J. W., Canadian Department of Munitions and Supply, Washington, D. C.
Pollack, D., Groton Long Point, Conn.
Shanck, R. B., 134 Manor Rd., Douglaston, L. I., N. Y.
Silver, M., 140 E. 28 St., New York, N. Y.

The following admissions to Associate were approved by the Board of Directors on November 3, 1943.

Adams, T. N., 953 Victory Dr., S.W., Atlanta, Ga.
Arnold, N. E., 109 Whitman Ave., Collingswood, N. J.
Arp, H. E., CAA Signals Training Center, R.F.D. 2, Box 10, Ft. Worth, Texas
Auxter, C. N., Fifth Student Sq., Bks., Fort Myers, Fla.
Bailey, A. D., Department of Electrical Engineering, University of Illinois, Urbana, Ill.
Barr, E. W., 1519 Olympian Way, S.W., Atlanta, Ga.
Barron, J. P., A.P.O. 825, c/o Postmaster, New Orleans, La.
Battie, R. G., 730 Leavenworth St., San Francisco, Calif. (transfer)
Bauler, J. W., 5028 Greene St., Philadelphia, Pa.
Bergan, K. M., 706 W. Second St., Northfield, Minn.
Berman, I., 485 W. 187 St., New York, N. Y.
Blinoff, W., Jr., 5820 N. Kenmore Ave., Chicago, Ill.
Blue, N. E., 2912 N. 12 St., Philadelphia, Pa.
Boland, C. E., 1169 Boulevard, N.E., Atlanta, Ga.
Booth, W. S., 169 Darrington St., S.W., Washington, 20, D. C. (transfer)
Boudon, A. P., 12½ E. Fourth St., Emporium, Pa.
Bouman, L. F., c/o Royal Netherlands Indies Airways, 521 Fifth Ave., New York, N. Y.
Brittain, V. M., 1204 N.W. 20 Ave., Portland, Ore.
Brown, E. E., 518 Russell St., Covington, Ky.
Brown, J., 410 Union Ave., Irvington, 11, N. J.
Buckley, E. F., 150 Bedford Rd., Toronto, 5, Ont., Canada (transfer)
Buitenkant, N., 1154 First Ave., New York, N. Y.
Burnett, K. H., 42 Oakland St., West Springfield, Mass.
Bush, B. E., Jr., North 1534 Cedar St., Spokane, Wash.
Butterfield, W. S., A.P.O. 958, c/o Postmaster, San Francisco, Calif.
Cadwallader, R. W., Jr., 1815 N. 50, Seattle, 3, Wash.
Campbell, E. W., 308 N. Cheney St., East Point, Ga.

(Continued on page 46A)

Here's **THE ONLY VARIABLE RESISTOR** with a **SOLID MOLDED ELEMENT**



Cross-section view showing how terminals are imbedded in solid, molded resistor element.

The resistor element in the Allen-Bradley Type J Bradleyometer has substantial thickness (approx. $\frac{1}{32}$ in. thick) and is molded as a single unit with the insulation, terminals, face plate, and threaded bushing. It is not a film, spray, or paint type resistor. Reliability and compactness are assured by this simple construction which eliminates all rivets, welded or soldered connections, and conducting paints. During manufacture, resistor material may be varied throughout its length to provide prac-

tically any resistance-rotation curve. Bradleyometers meet Army and Navy 200-hour salt spray tests.

Bradleyometers are the only continuously adjustable composition type resistors (only one inch in diameter) having a rating of two watts with a good safety factor. Available in resistance values as low as 50 ohms. They can be supplied for rheostat or potentiometer uses, with or without a switch. Write for specifications today. Allen-Bradley Company, 114 W. Greenfield Ave., Milwaukee 4, Wis.



Type J Bradleyometers may be used separately or in dual or triple construction to fit any particular control need.

FIXED RESISTORS



Type GB Insulated 1-Watt Fixed Resistor



Type EB Insulated $\frac{1}{2}$ -Watt Fixed Resistor

Actual size sectional views of Bradleyunits showing the molded homogeneous resistor material, insulation, and imbedded lead wires. Overall lengths: Type GB— $3\frac{1}{8}$ in.; Type EB— $3\frac{3}{8}$ in.



ALLEN-BRADLEY

FIXED & VARIABLE RADIO RESISTORS

QUALITY

INTEGRITY OF DESIGN

... a phrase that tells
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The phrase, *Integrity of Design*, has come to typify that "lengthened shadow" behind the business of creating Jackson Instruments. Like Topsy, it "just grewed" into our thinking and into our work. Today it constitutes our inspiration—and our constant challenge, permeating every phase of anything we do.

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 Chadbourne, H. L., 2745—29 St., N.W., Washington, D. C.
 Clarke, A. C., "Ballifants," Bishops Lydeard, Taunton, Somerset, England
 Cohn, G. I., 265 Woodland Rd., Lake Forest, Ill. (transfer)
 Cole, D. R., Comm. Depr., Gen. Sec., Antiaircraft Artillery School, Camp Davis, N. C.
 Cox, E. B., 30 Girton Ave., London, N.W., 9, England
 Downey, R. F., 132 Jay St., Apt. 8, Schenectady, N. Y.
 Dresch, R., 4044 Harding Ave., Cheviot, Ohio
 Drougalis, J. V., 101-21—107 St., Richmond Hill, L. I., N. Y.
 Elliott, A. W., 157 Maplewood Ave., Toronto, Ont., Canada
 Ewald, E. E., RCA Manufacturing Co., Lancaster, Pa.
 Fasick, R. C., 1739 W. Devon Ave., Chicago, Ill.
 Felton, W. W., 603 Hillborn Ave., Swarthmore, Pa.
 Ferl, R. H., 1240 Edmond Dr., Rosemead, Calif.
 Fichtl, R. R., 69 Sinniger Pl., Maywood, N. J.
 Finkelstein, R. L., A. P. O., 640, c/o Postmaster, New York, N. Y.
 Fletcher, K. L., 3333 N. Marshfield Ave., Chicago, Ill.
 Floyd, W. B., Jr., Electrical Engineering Department, Stanford University, Calif.
 Formby, J. K., 39 Victoria St., Burwood, N. S. W., Australia
 Franklin, P. J., 3855 Rodman St., N.W., Washington, 16, D. C.
 Freeman, R. W., 117 Nott Ter., Schenectady, N. Y.
 Fritschi, W. W., Bell Telephone Laboratories, 463 West St., New York, N. Y.
 Fromer, J., 114 E. Third St., New York, 3, N. Y.
 Furedy, F., 1400 Lakeshore Dr., Chicago, Ill.
 Garity, N. O., 58 W. 72 St., Chicago, Ill.
 George, J. E., 88 Blaine Ave., Buffalo, 8, N. Y. (transfer)
 Gieffers, H. W., 4045 N. LaPorte Ave., Chicago, 41, Ill. (transfer)
 Gilmore, A. C., Jr., 209 Post Ave., Lyndhurst, N. J.
 Glade, H. E., 1537 S. 12 St., Milwaukee, 4, Wis.
 Graim, R. J., 970 National Press Bldg., Washington, D. C.
 Greene, M. B., 227 North Aphir, Apt. B., Stockton, Calif.
 Gruenberg, E. L., 3014 Clarendon Rd., Brooklyn, N. Y.
 Hall, T. S., 514 Pilchuck Path, Everett, Wash.
 Harrell, L. B., 311 W. Cleveland Ave., East Point, Ga.
 Hayden, L. B., 2130 Como Ave., St. Paul, 8, Minn.
 Hearsom, D. R., 1785 Massachusetts Ave., Washington, D. C.
 Herbert, C., U. S. Coast Guard, 414 Insurance Bldg., Seattle, Wash. (transfer)
 Hicken, J., 54 Elm St., Belmont, 78, Mass.
 Hinshaw, R. M., c/o W. E. Hinshaw, Box 475, Mt. Home, Idaho
 Holland, H. A., 5038 Waveland Ave., Chicago, 41, Ill.
 Holtz, R. F., 6159 Cedar Ave., Merchantville, N. J.
 Hudgins, W. D., Radio Material Officer, Navy 117, c/o Fleet Post Office, New York, N. Y.
 Hughes, W. R., 10849 Parr Ave., Sunland, Calif.
 Jacob, C. W., Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.
 Jeffries, C. D., Radio Research Laboratory, Harvard University, Cambridge, Mass.
 Jones, F. F., Hq. Fourth Airways Communications Region, 581 Peachtree St., Atlanta, Ga.
 Jordan, W. H., Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.
 Kahal, R., 330 E. 71 St., New York, 21, N. Y.

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Klemm, G. H., 189 Belleville Rd., New Bedford, Mass. (transfer)

Kelly, J. M., 645 N. Jackson St., Arlington, Va.

Keller, C. A. R., 4 W. Sixth St., Emporium, Pa.

Kelsey, L. E., 941 N. Linwood Ave., Indianapolis, 1, Ind.

Kessel, R. L., 151 S. Wisconsin Ave., Villa Park, Ill.

King, B. A., Jr., 10 Alden Pl., Bronxville, N. Y.

Kipp, L., 8268—168 St., Jamaica, L. I., N. Y.

Lonrad, W. L., 1133 Chislett St., Pittsburgh, 6, Pa.

Kopp, R., 736 Rock Creek Church Rd., N. W., Washington, 10, D. C.

Koury, E. J., 45 W. 75 St., New York, N. Y.

Kunz, K. S., 128 Oxford St., Cambridge, 40, Mass.

Lindberg, A. F., 7714 N. Haskins Ave., Chicago, 26, Ill.

Lindsey, J. G., 5732 N. Winthrop Ave., Chicago, 40, Ill.

Lumsden, R. B., 59 Station Road, Mimico, Ont., Canada

McKowen, P. B., Hadnot Point, New River, N. C.

Meader, H., 3430 South Hill St., Los Angeles, Calif. (transfer)

Meadows, F. D., RCA Victor Division, 501 North LaSalle, Indianapolis, Ind.

Melius, F. G., 1482 Iglehart Ave., St. Paul, 4, Minn.

Middleton, R. G., 8 Rossie St., Mystic, Conn.

Moffet, V. J., 6938 South Laffin St., Chicago, 36, Ill.

Mollenauer, J. H., R.D. 1, 84, Pa.

Mozley, R. F., 351 Front St., Hempstead, L. I., N. Y.

Murphy, C. H. S., Naval Research Laboratory, Anacostia Station, D. C. (transfer)

Nidzyn, J. J., Merrick Rd., Speonk, L. I., N. Y.

Norris, C. A., 628 Huron St., Toronto, Ont., Canada

Odell, N. H., 229 Cobbs Hill Dr., Rochester, N. Y.

Pardell, M. K., 1031 Pierson Rd., Flint, Mich.

Penners, B. A., 757 E. 13, Idaho Falls, Idaho

Pine, C. C., 3015 Morgan St., Apt. 57, Seattle, 8, Wash.

Plinsky, J. D., 3536 W. 13 Pl., Chicago, Ill.

Paulson, W. A., Rm. 657, Bell Telephone Laboratories, 463 West St., New York, N. Y.

Redman, W. T., 35 S. Howard St., Bellevue, Pittsburgh, 2, Pa.

Revercomb, H. E., 7069 Sheryl Dr., Norfolk, 5, Va. (transfer)

Rice, S. M., 1902—23 St., S.E., Apt. 93B, Washington, D. C. (transfer)

Rothschild, R. F., 54 Willow Ave., Hempstead, L. I., N. Y. (transfer)

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Schmidt, P. S., Research Laboratory, Stromberg-Carlson Co., Rochester, N. Y.

Schwartz, H. E., Jr., 620 Main St., New Rochelle, N. Y. (transfer)

Scullin, C. H., 111 Dodd St., East Orange, N. J.

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Selleck, R. S., 6730 Fourth Ave., Los Angeles, 43, Calif. (transfer)

Shallcross, G. P., 4713 Pensacola Ave., Chicago, Ill.

Smith, B., Jr., 111½ Miller St., Maryville, Tenn.

Sonnemann, H., 91 Ft. Washington Ave., New York, 32, N. Y.

Speight, N. H., 145 Wellington St., West, Toronto, Ont., Canada

Stann, L., 3936 W. 56 Pl., Chicago, Ill.

Starek, R. A., 107 W. Fourth St., Emporium, Pa.

Steen, W. J., Applied Physics Laboratories, Johns Hopkins University, Silver Spring, Md.

Stenger, F. J., 6619 Pine Ave., Bell, Calif.

Stiepel, G. W., 22—17—119 St., College Point, L. I., N. Y.

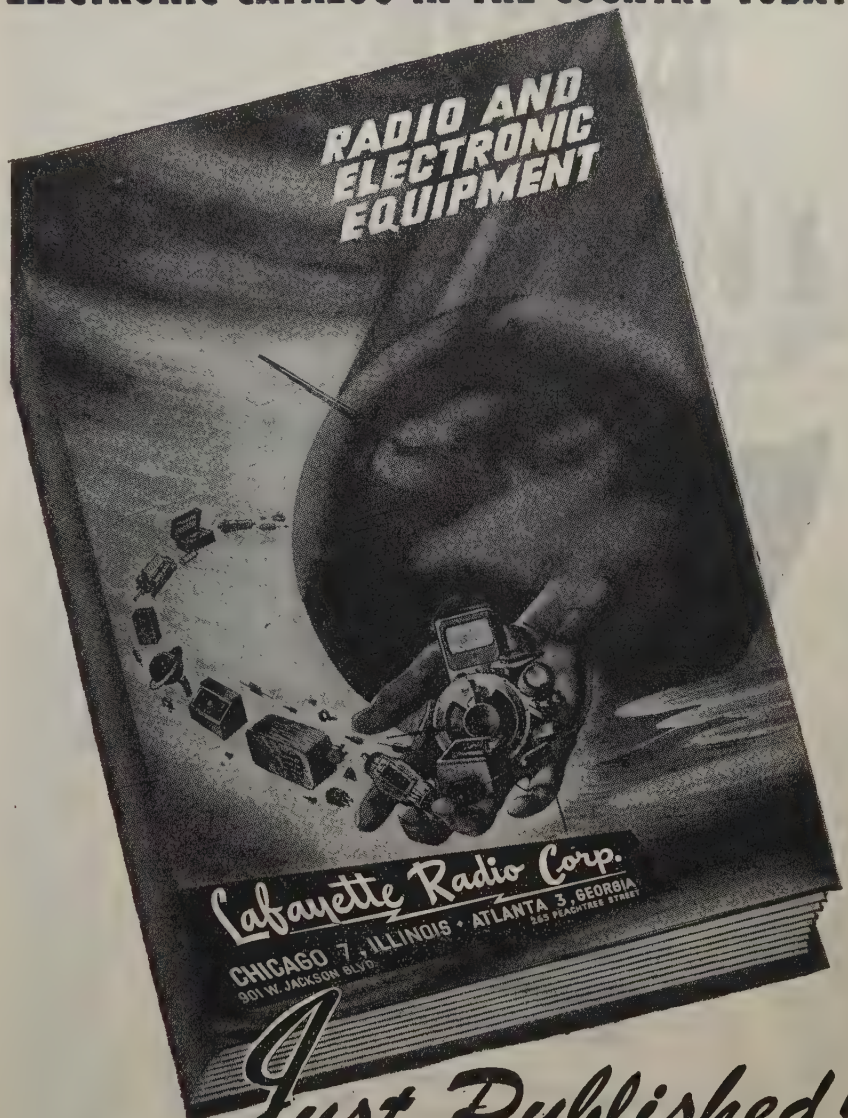
Strong, J. A., 3128 Dove St., San Diego, Calif.

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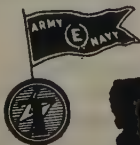


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Thompson, R. R., 48 Schley Blvd., Bremerton,
Wash.
Toomey, J. W., 2925 O St., S.E., Washington, 20,
D. C.
Veck, H., 2009 Fairlawn Ave., S.E., Washington,
20, D. C.
Venable, D., 1511 Bolton St., Baltimore, 17, Md.
Wathen, R. L., Sperry Gyroscope Co., Garden City,
L. I., N. Y.
Weinstein, G., 705 East Thomas, Seattle, Wash.
Wheeler, H. S., "Kildare," Manby Rd., Gt. Mal-
vern, Worcestershire, England
Whittemore, H. B., 160 High St., Middletown,
Conn.
Wilkins, O. L., 3805 W St., S.E., Washington, 20,
D. C.
Williams, C. K., 680 Lee St., S.W., Atlanta, Ga.
Wilson, J. H., Civil Aeronautics Administration,
Box 23, Ogden, Utah
Wolff, J., 27 Howard Ave., Brooklyn, N. Y.
Woodward, P. J., 6956 Calumet Ave., Chicago, Ill.
Young, M. L., 64 E. College, Oberlin, Ohio

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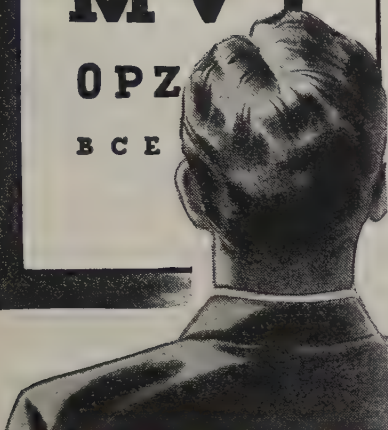
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Altman, F. J., Box 2917, Tampa, Fla.
Armstrong, E. A. Armstrong, 473 Embarcadero,
Palo Alto, Calif.
Armstrong, H. W., 4431 N. Rockwell St., Chicago,
Ill.
Baker, N. A., 276 Church St., Newton, Mass.
Baltimore, D. M., 222 Babcock St., Brookline,
Mass.
Barkley, F., Box 21, Medfield, Mass.
Bartelink, E. H., R.F.D. 3, West Wilton, Ballston
Spa, N. Y.
Barth, E. G., 71st Coast Artillery, Fort Story, Va.
Baxter, Charles, 298 Banbury Rd., Oxford, England
Beckman, J. A., 2309 Chickasaw St., Cincinnati,
Ohio
Black, Jr., A. O., 1714 Massachusetts Ave., N.W.,
Washington 6, D. C.
Bloom, Abraham, Rumson Area "C.E.S.L.," Rum-
son, N. J.
Bode, R. H., 1200 Louisiana, Lawrence, Kan.
Bramhall, E. H., 22 Bay State Rd., Boston, Mass.
Brelsford, Howard, 4550 Linden Ave., Norwood,
Ohio
Brown, J. N., 148 Elm St., Franklin, Pa.
Buchter, T. W., Fort Monmouth New Jersey.
Burr, R. P., 214 Foulke Hall, Princeton, N. J.
Calister, R. A., 19 S. Wolcott St., Salt Lake City,
Utah
Campbell, R. E., 410 W. 110 St., New York, N. Y.
Capps, J. H., 1409 Monroe St., Corvallis, Ore.
Checks, J. A., 2300 Fairdale Ave., Cleveland, Ohio.
Christenson, C. K., 334 Lincoln Ave., Palo Alto,
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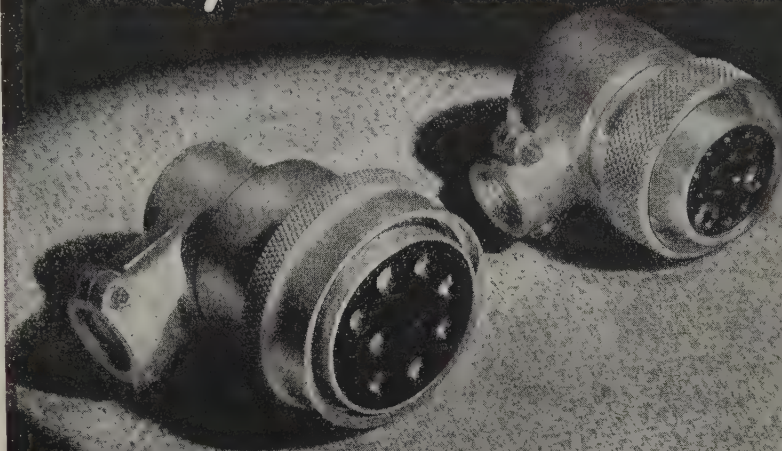
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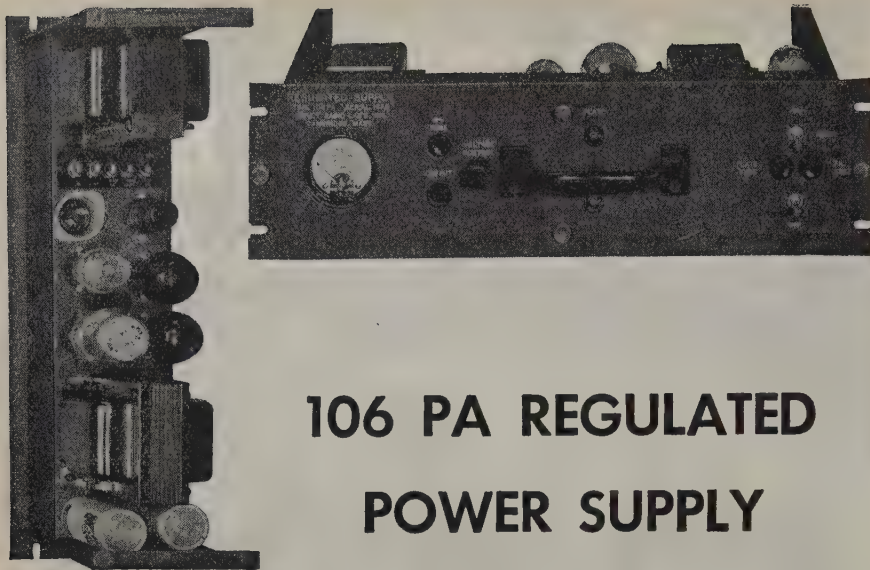
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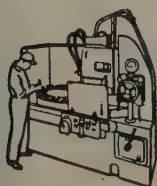
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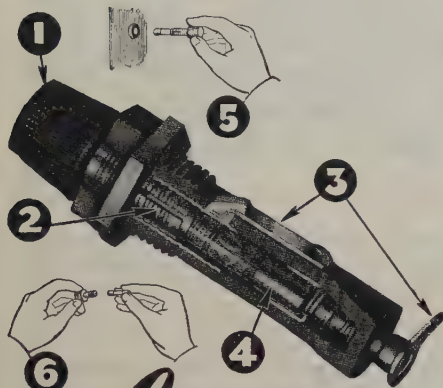
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Crabb, R. C., 1229 Mt. Vernon Ave., Dayton, Ohio
Crain, C. M., 510½ W. 18 St., Austin, Tex.
Cramer, K. H., 740—16 Ave., N., Seattle, Wash.
Cunningham, J. C., Rm. 12, Yatoka Hall, University of New Mexico, Albuquerque, N. M.
Dacewicz, L. N., Box 305, College Station, Durham, N. C.
Daniels, H. R., San Juan, Puerto Rico.
Denonn, P. A., 135 Jamaica Ave., Brooklyn, N. Y.
Donovan, W. E., 40 E. 49 St., New York, N. Y., c/o L. P. Graner
Dreyer, Jr., J. F., 2315 Foster Ave., Brooklyn, N. Y.
Dufourd, A. J., Box 128, Schenectady, N. Y.
Evans, W. G., Apt. 6, 119 S. Linn, Iowa City, Iowa
Fish, William, 621 Leverette, Fayetteville, Ark.
Fitting, F. N., 1583 Massachusetts Ave., Cambridge, Mass.
Gaffrey, J. A., 519 University Ave., Grand Forks, N. D.
Gardner, F. H., 5831 Philadelphia Dr., Dayton, Ohio
Gardner, R. S., 45 E. High St., Ballston Spa, N. Y.
Garrett, E. T., 808 Union Ave., Belleville, Ill.
Gates, H. W., 506 Wisconsin Ave., Oak Park, Ill.
Geisert, W. O., 2512 E. Union St., Seattle, Wash.
Gerstein, Michael, A.P.O. 958, c/o Postmaster, San Francisco, Calif.
Gervais, W. A., 16 Mellen St., Cambridge, Mass.
Gibson, Robert, University Station, Gainesville, Fla.
Glan, George, 471 Grand Ave., Dayton, Ohio
Goodstine, Herman, 148 Bissell St., Manchester, Conn.
Guest, J. W., 1336 Glenwood Rd., Glendale, Calif.
Haacke, E. M., 276 University Ave., Kingston, Ont. Canada
Hagenbuch, W. H., Graduate House, Massachusetts Institute of Technology, Cambridge, Mass.
Halsall, Michael, 123 Waverly Pl., New York, N. Y.
Hamrey, S. D., A.E.T.C., Austin Hall, Harvard Univ., Cambridge, Mass.
Harvey, H. F., 333 W. 88 St., New York, N. Y.
Hawley, P. F., 7339 S. Coles Ave., Chicago, Ill.
Henrich, W. H., 144 Brattle St., Cambridge, Mass.
Hodgers, R. W., 339 W. Berry St., Fort Wayne, Ind.
Hoepfer, H. B., 153 Arden Park, Detroit, Mich.
Hoffman, R. W., A.P.O. 617, Douglas Aircraft Corp. c/o Postmaster, New York City
Hofheimer, R. W., Harvard Univ., Cambridge, Mass.
Hollyer, Jr., R. N., 15906 Blackstone, Detroit, Mich.
Homewood, Charles, Casoc Bahrein Island, Persian Gulf.
Hykal, F. A., 14150 Young St., Detroit, Mich.
Inns, S. H., 1241 Agate St., San Diego 9, Calif.
Instrall, R. C., Catterick Camp, Yorkshire, England.
Jackson, J. K., 144 Brattle St., Cambridge, Mass.
Jellinek, Ernest, 13 State St., Schenectady, N. Y.
Jennett, Jr., N. E., Y.M.C.A., Rm. 422, Hunt Ave. Boston, Mass.
Johnson, J. L., Forest Ave., Eden Ter., Catonsville, Md.
Johnston, R. B., Cruft Laboratory, Harvard University, Cambridge, Mass.
Jungerman, J. A., Bowles Hall, Berkeley, Calif.
Kannanstone, F. M., 1922 W. Gray Ave., Houston, Texas
Kantenberger, W. J., 740 S. Hampton Rd., Dallas, Texas
Kaye, Philip 1025 Linwood Ave., Apt. A, St. Paul, Minn.
Kelar, Joseph, 52 S. Walnut St., East Orange, N. J.
Kercher, T. C., Atlantic Fleet Schools, Radio Nob, Norfolk, Va.
Kleeb, G. F., 145 Grant Ave., Etna, Pa.
Knox, D. N., c/o Douglas Aircraft Co., A.P.O. 617, Postmaster, N. Y.
Koch, R. F., 436—43 St., West Palm Beach, Fla.
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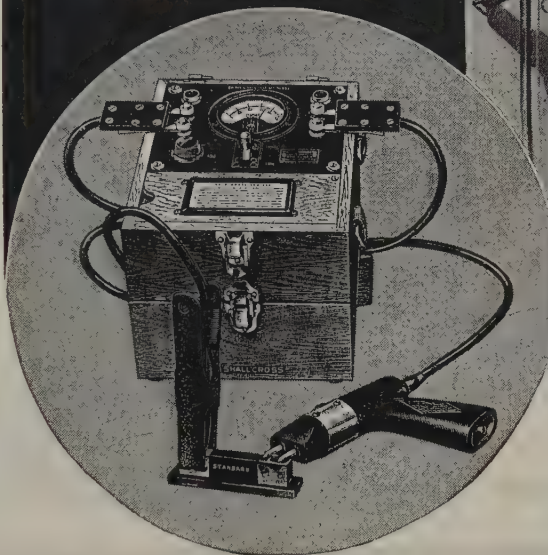
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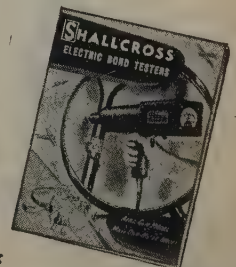
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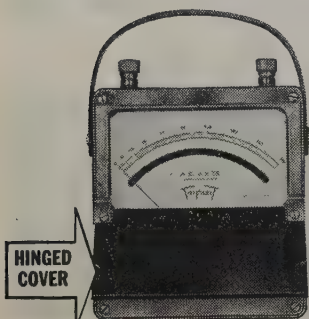
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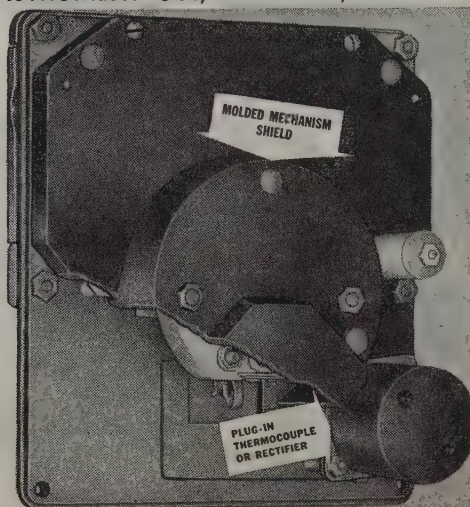
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- Lewis, H. G., 16 Langdon St., Madison, Wis.
- Lines, S. R., 1309 Easton Ave., South Bellingham, Wash.
- Little, W. A., 605 Mt. Prospect Ave., Newark, N. J.
- Lundwall, G. F., Second Communications Sqdn., Patterson Field, Ohio
- Lyman, C. H., 308 S. Sixth St., Bozeman, Mont.
- Mack, R. A., Leverett F-41, Cambridge, Mass.
- Marriner, A. W., Headquarters, Army Air Forces, Washington, D. C.
- McCord, H. W., 1928 Geddes Ave., Ann Arbor, Mich.
- McKee, D. I., 38 N. Woodward Ave., Dayton, Ohio
- McLeod, K. A., 9727 Sutherland Rd., Silver Spring, Md.
- McReynolds, Z. A., Box 99, Palestine, Texas
- Mesch, F. A., 913 1/2 South Jenkins, Norman, Okla.
- Michaelson, M. W., 707—28 St., Sioux City 18, Iowa
- Muller, F.A., 740 Riverside Dr., Apt. 5G, New York N. Y.
- Nelson, A. L., Riverview Add, Rt. 10, North Kansas City, Mo.
- Newson, J. V., H.Q. 209 Group, Royal Air Force, Middle East Forces
- Ogden, B. W. 26 M. Dod Hall, Princeton, N. J.
- Pennycook, W. D., Box 1828, Stanford, Calif.
- Perrino, Salvatore, Shell Pipe Line Corp., Rm., 1209, Shell Bldg., Houston, Texas
- Predmore, E. E., 1746 Cambridge St., Cambridge, Mass.
- Procter, E. N., 2276 Shattuck Ave., Berkeley, Calif.
- Pumphrey, F. H., 4621—23 St. N., Arlington, Va.
- Putzrath, F. L., 15 W. Harrison, Iowa City, Iowa
- Radcliffe, J. C., Eagle River, Wisconsin
- Regen, B. R., 1224 Cottage Pl., N.W., Canton, Ohio
- Reich, A. L., 927 Beacon Ave., Los Angeles, Calif.
- Reynolds, Jr., G. E., Box 1687, University of Maryland, College Park, Md.
- Rigle, Bernard, 23 Bristol St., Brooklyn, N. Y.
- Ringwalt, D. L., 3003 Seventh, S.E., Washington, D. C.
- Riordan, N. F., 49 Norwood Ave., Clifton, S. I. N. Y.
- Rissler, H. D., WHO, Central Broadcasting Co., Hughesville, Wis.
- Rocke, Arthur, 100 Varick St., New York, N. Y.
- Ross, J. M., 406 Stewart Ave., Ithaca, N. Y.
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- Sheve, H. C., 1023 Flower Ave., Takoma Park, Md.
- Sievers, W. C., 619 Bixby Ave., Bellflower, Calif.
- Silberstein, Richard, 34 Bexhill Dr., Kensington, Md.
- Slater, F. R., R.C.A. Communications, Bolinas, Calif.
- Steiner, J. R., 1151 Alba St., Mobile, Ala.
- Stevens, A. M., 404 Riverside Dr., Apt. 11B, New York, N. Y.
- Stites, F. H., 209 Greene Ave., Brooklyn, N. Y.
- Stokes, E. G. C., c/o Forbes School, Swanage, Dorset, England
- Story, H. O., Almo, Ky.
- Tandberg, W. E., 1730 La Loma Ave., Berkeley, Calif.
- Taylor, A. H., Box 90, Rt. 2, Anacostia Station, D. C.
- Thomas, H. E., 102 Elm Ave., Haddonfield, N. J.
- Thompson, Kenneth, 19 Garden St., Cambridge, Mass.
- Thornberry, H. C., Y.M.C.A., 316 Huntington Ave., Boston, Mass.
- Tristani, Jr., J. E., N. T. Sch., Harvard Univ., Cambridge, Mass.
- Tuckerman, L. P., Federal Telegraph Co., 200 Mt. Pleasant Ave., Newark, N. J.
- Vandermause, O. J., 1457 Fairmont St., N. W., Washington 9, D. C.

(Continued on page 58A)

Proceedings of the I.R.E. December, 1943

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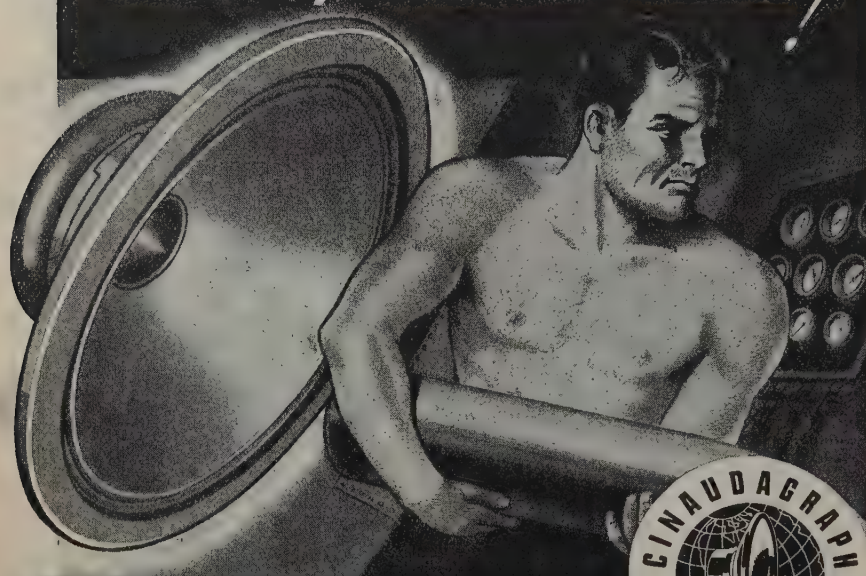
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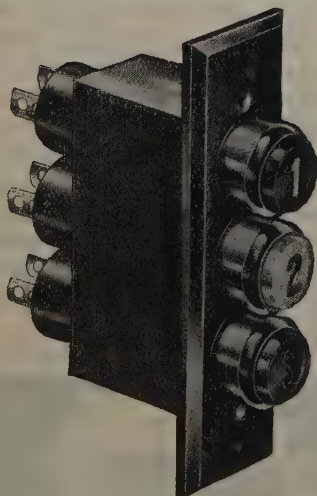
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Incorrect Addresses

(Continued from page 56A)

- Van Doren, M. L., 745 S. Normandie, Los Angeles, Calif.
 Waer, R. R., Box 371, Easton, Pa.
 Wakefield, E. H., 5646 Kenwood Ave., Chicago, Ill.
 Waychus, F. J., A P O 4002, c/o Postmaster, New York, N. Y.
 Wiggin, J. F., 27 Priscilla La., Schenectady, N. Y.
 Williams, L. B., 18 Prescott St., Cambridge, Mass.
 Willner, M. J., Box 2355, Georgia School of Technology, Atlanta, Ga.
 Wolf, S. B., 225 W. Lutz St., West Lafayette, Ind.
 Wood, W. L., Fort Bragg, N. C.
 Woodruff, C. W., Georgia School of Technology, Atlanta, Ga.

Television Relay Network

Nation-wide television networks made possible by automatic radio relay stations and other new developments, which eventually are expected to lead to finding the key to international television, are a postwar prospect, according to Ralph R. Beal, assistant to the vice president in charge of RCA Laboratories.

A radically new form of "lighthouse" radio relay station developed by the Radio Corporation of America engineers will make relaying of television programs a relatively simple matter, according to Mr. Beal. He envisages that these unattended relay stations located 20 to 50 miles apart will not only link television stations into national networks but will open up a new era in international communications, through development of trunk lines over such vast areas as Russia and China.

"It is to be expected," he stated, "that television stations will first go on the air in such broadcasting centers as New York, Chicago, and Los Angeles. But there is every indication that alert broadcasters will keep pace with them in such localities as Boston, Philadelphia, Washington, Pittsburgh, Cleveland, Detroit, St. Louis, Kansas City, Omaha, Denver, and San Francisco. It seems logical to assume that the first television network linked by radio relay stations will be formed along the Atlantic Seaboard.

"But television will not be limited to the larger cities. The radio map will be dotted with stations in cities like Schenectady, Utica, Syracuse, Minneapolis, Erie, Buffalo, Louisville, and many others. By the use of radio relays, these two will become outlets for the television network which before many years pass after the war, will weave from the east across the Mississippi and the midwest plains to meet a Pacific Coast link striking eastward across the Rockies. A relay station atop Pike's Peak might well be the key station to complete a transcontinental television chain."

Pointing out that radio relay stations may also bring about a vast change in world-wide communications, Mr. Beal explained that, "the routes of these radio relays will extend to any part of the world. They can go through the jungles, from island to island, across mountains and the polar wastes. Neither tropical heat, nor arctic snow,

(Continued on page 60A)



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Voice Communication Components



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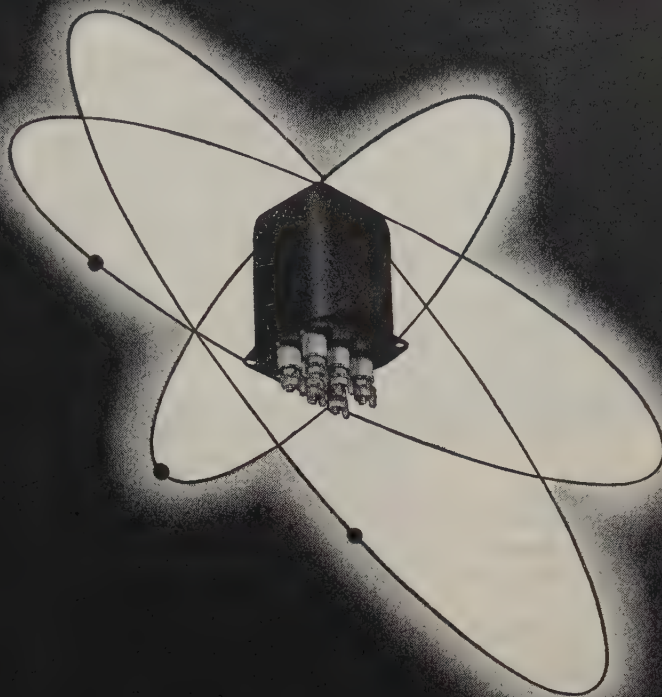


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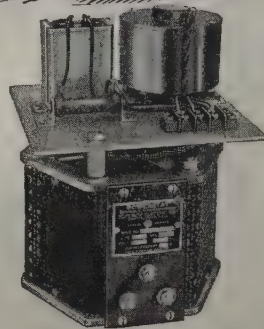
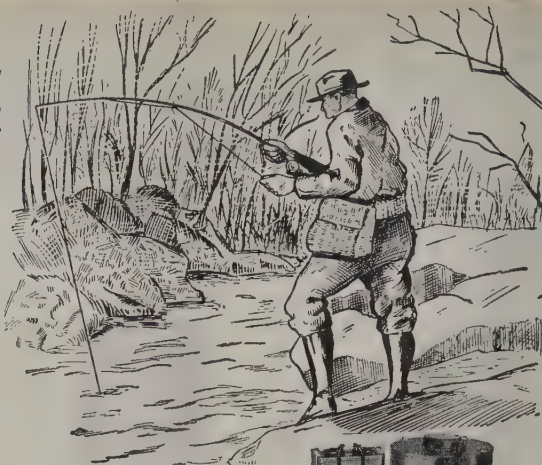
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Television Relay Network

(Continued from page 58A)

neither fog nor hurricane will 'cut' the global lines. They can be built to be practical, efficient, and foolproof.

"Just think what television trunk lines will mean to China," he continued. "I have been there and I feel that I know how welcome the new art of radio relaying will be to the millions of Chinese, for it will bring them communications, entertainment, and education on a scale they have never known. What a gigantic task it would be to wire all China and its great open spaces for sound. But how much easier it will be to do the job by 'wireless,' to dot the countryside with relatively inexpensive radio relay transmitters that will given to China a trunk-line system of communication for television, radio, telephone, and telegraph. Even the Himalayas will be no barrier to such radio relaying. Their high mountain peaks will speed the process, for relay stations at such altitudes can reach far beyond the horizons of the valley. China will then have a new Burma Road—a road of television."

It was explained that radio relaying will be a comparatively simple process. The relay transmitters will operate on microwaves with the energy concentrated almost in a beeline. Practically all the power is made to serve a useful purpose; it is not scattered as in broadcasting. Therefore, relatively small amounts of power will operate the relay transmitters. The apparatus is neither cumbersome nor complicated. It is simple and compact. It could not be otherwise and still perform in the domain of tiny wavelengths which bring radio men so close to the frontiers of light, he said.

"We know, of course," continued Mr. Beal, "that ultra-short waves and centimeter waves travel in a straight line and leave the earth on a tangent at the horizon. The area of the earth's surface touched by such waves, is much like that touched by a stick held against a basketball. Obviously, if we use high towers or antennas on lofty buildings or mountain peaks, we capture and retransmit the waves at higher levels, and therefore their effective range is lengthened. With the use of radio relay stations, the average range is about 30 miles, depending upon the terrain and various other factors. It is interesting to recall that an airplane over Washington, D. C., carrying a television receiver intercepted the pictures from the NBC aerial on the dome of the Empire State Building 200 miles away. But for such long-distance reception of the ultra-short waves, the plane had to go up 20,000 feet."

The radio relay system is to be no one-way ethereal street as Mr. Beal charts it. Multiple channels make it all the more promising in efficiency, flexibility, and service. The relay towers will handle numerous circuits, for example, down and back from New York to Washington. Furthermore, the circuits can be multiplied to any reasonable extent, not only to carry one television program but several simultaneously, as well as frequency-modulation sound broadcasts, telegraphic traffic, and facsimile. In fact, relay circuits should be among the busiest in the air.

The main relay system, envisaged by Mr.

(Continued on page 62A)

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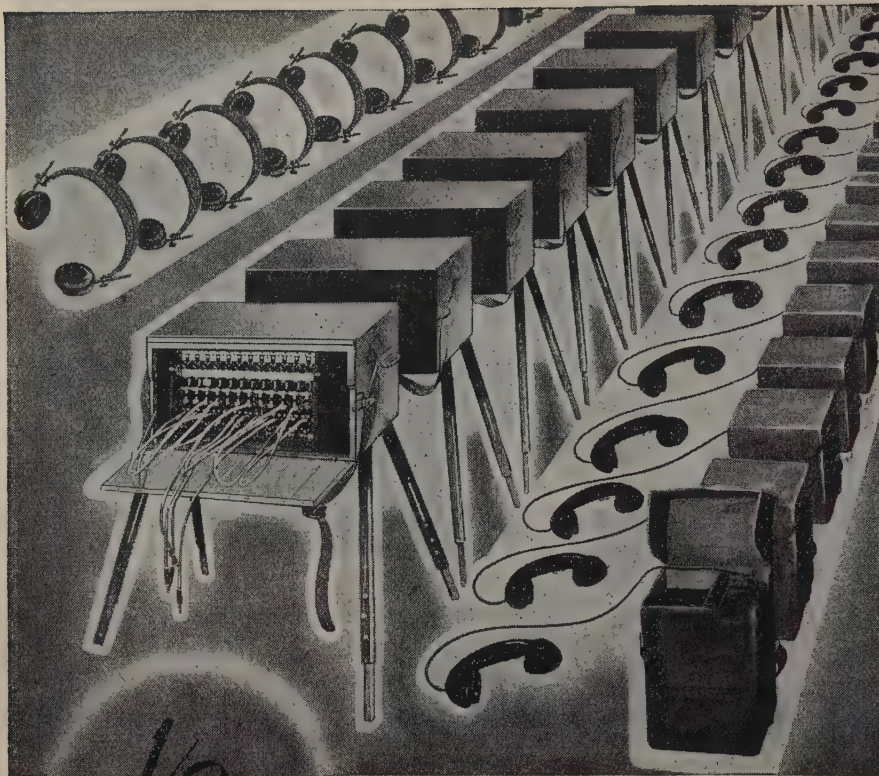
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Television Relay Network

(Continued from page 60A)

Beal, will be like a great intercity spine, becoming interstate and eventually transcontinental. The ribs will spread to television stations. To illustrate its possibilities, he describes it as it is likely to function between New York and Washington: While the NBC television program is being broadcast from the aerial on top of the Empire State Building, a different program will be originating in Washington. Both programs will be fed simultaneously into the relay system leading from Manhattan Island through Philadelphia to the nation's capital. One Philadelphia station can elect to broadcast the program from New York, while another taps the relay channel carrying the program staged in Washington.

Also, if a New York station, aside from the NBC transmitter, desires to broadcast the Washington program it can do so by tapping the relay channel. In this way, the relay system becomes a trunk line that can be tapped at will by the television stations, thereby affording greater freedom of program selection and operation. The relay enhances variety in programming, because there may be four or five relay channels simultaneously carrying different programs, which can be selected by the main television stations.

"Of course it will be understood," concluded Mr. Beal, "that I have spoken of these technical developments from the standpoint of the engineer. I realize, as do others, that it will take money to establish such a radio relay system as I have described. Indeed, it will take more than money. It will require a sympathetic and helpful attitude on the part of governmental agencies concerned with licensing and regulation and the daring spirit of the American industrial pioneers who have led the way in so many new developments."

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The record of the telephone equipment manufacturing industry in this war should be a sufficient guarantee that our fighting men will continue to get what they need, regardless of the enormity of the job.

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We submit the record we are compiling now, as evidence of ability to serve postwar America. We are glad to consult with manufacturers seeking help on electronic or electrical product developments — also with engineers who have developed ideas that might round out our postwar plans.

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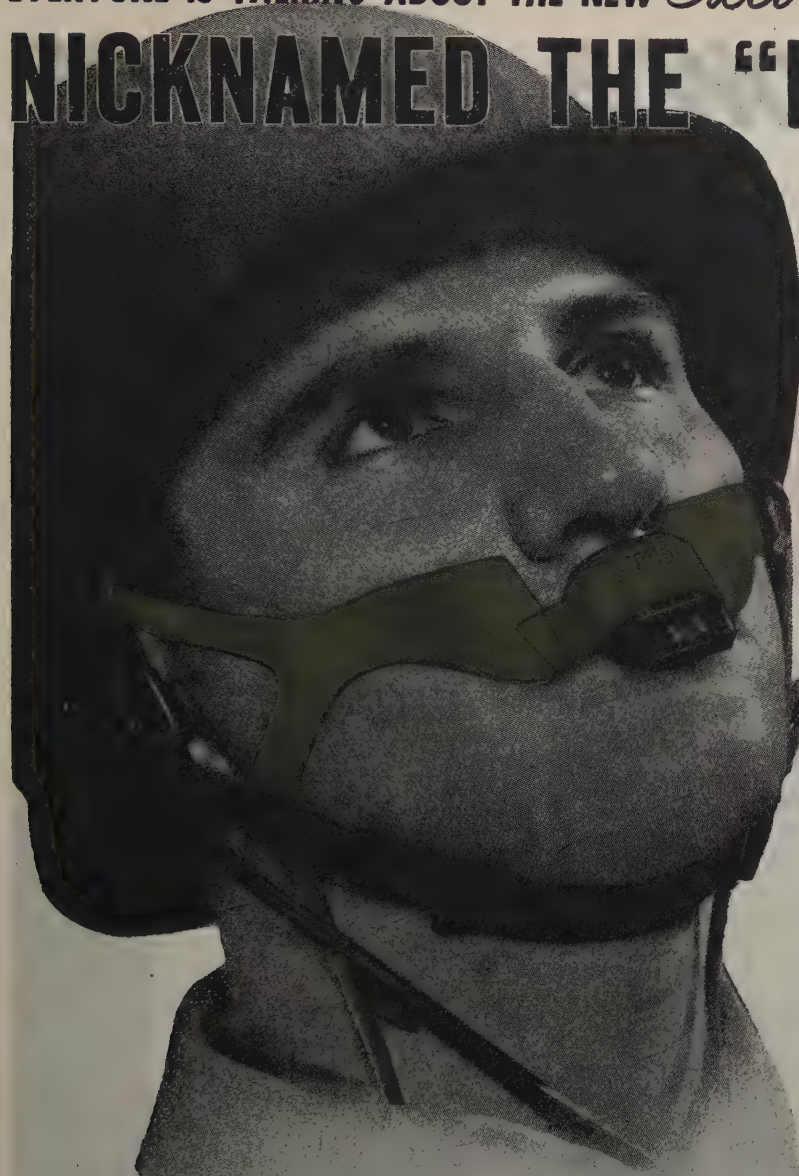
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Body No. 400	Description of Material
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I



Comparative Analysis of 3 Corning Coil Form Methods

	MULTIFORM COIL FORMS	BLOWN COIL FORMS	PRECISION GROUND COIL FORMS
O. D. Diameters	9/16" to 12"	1" to 3"	1/4" to 1 1/2"
Lengths	0.70" to 10 1/2"	2 1/2" to 9"	1/2" to 6"
Wall Thickness	3/32" to 7/8"	1/8" to 3/8"	3/64" to 3/16"
Maximum Threads per inch	32	12	24
Tolerance	± 2% but not less than ± 0.010" on all dimensions	± 0.015" on root diameter of thread	± 0.002" on root diameter of thread
Holes	Mold formed	Punched or ground	Punched or ground
Metallizing	Yes	Yes	Yes
Types of Glass	No. 790 Only	No. 707 or No. 774	No. 707 or No. 774

Comparative Properties of Corning Coil Form Glasses

	# 790	# 707	# 774
Maximum Operating Temperature (°C)	800	425	500
Linear Expansion (0-300°C) per °C x 10 ⁻⁷	8.5	31	32
Water Absorption—24 hrs. (%)	<.04	None	None
Volume Resistivity log R at 20° C	13.0	17.0	14.7
S.I.C.—20° C—1 MC	4.0	3.95	4.65
P.F.—20° C—I MC(%)	0.18	0.06	0.42
L.F.—20° C—I MC(%)	0.72	0.24	1.95

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This exclusive Corning Glass Works' method offers coil forms with all-round superior electrical characteristics . . . yet moderately priced in any quantity. Low coefficient of expansion. Most adaptable to complicated shapes or where multiple holes are required. Good thread contours. Can be metallized for applying mounting assemblies or terminal clips. Made from No. 790 glass only.

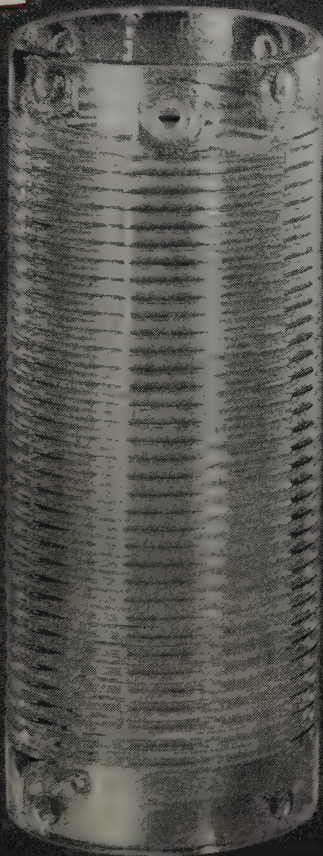
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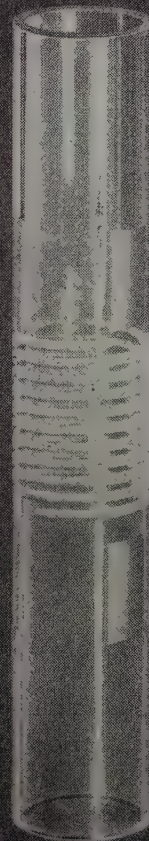
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In minimum quantities of 12,000 to 15,000 units for No. 774 glass, this Corning method provides coil forms at rock-bottom prices. Forms are unusually strong mechanically and are transparent for easy inspection of internal assemblies. Can be metallized for applying mounting assemblies or terminal clips. Can also be made from No. 707 glass in limited quantities by hand molding, for the duration.

3



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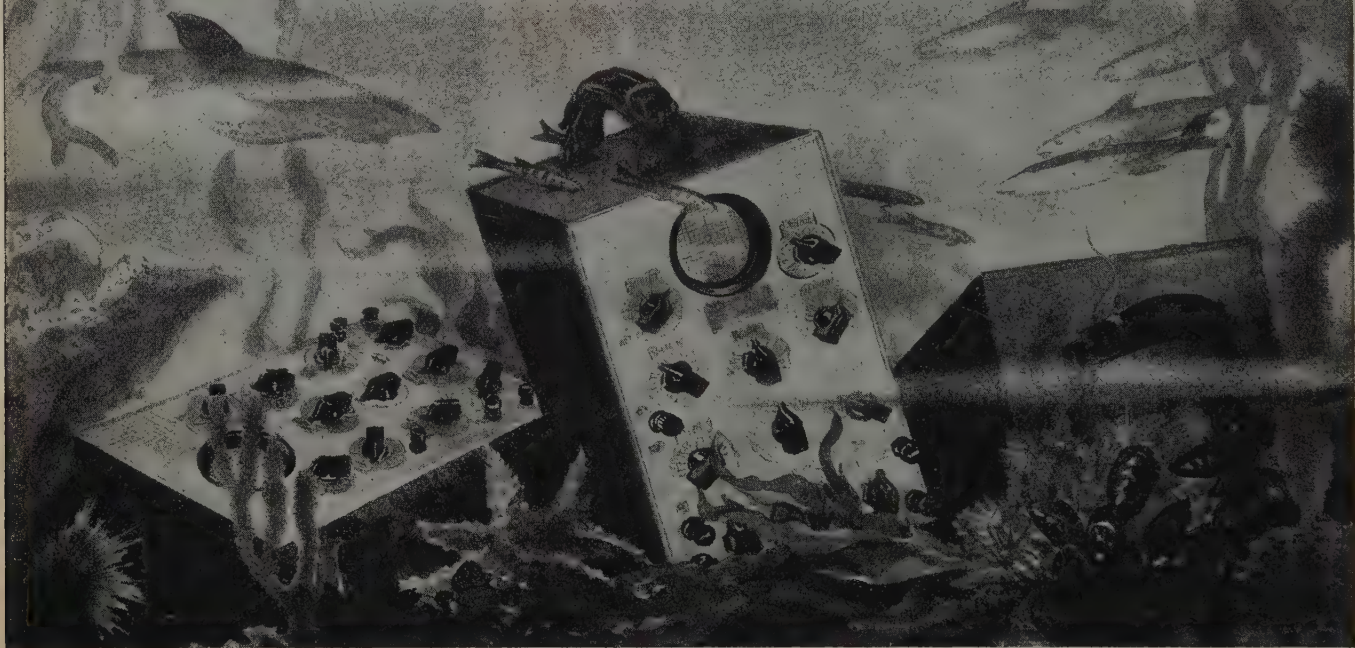
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Company.....
Street.....
City..... State.....

Submerged

IN SALT WATER . . .



YET FOUND STILL OPERATIVE WHEN CHECKED UP

► Quite by accident, three DuMont Type 164E 3-inch oscillographs were submerged in salt water. Duly recovered, they were returned for salvage—repair, if at all possible; otherwise, replacement.

Our service engineers were frankly disconcerted by the mud, silt and even seaweed found amidst the multitudinous components. Finally cleaned up, the instruments were checked for necessary repairs and replacements. And then the surprise:

Two instruments were found still operative! The third required only a potentiometer replacement for restoration to full operative condition!

While we do not recommend dunking as a regular thing, we submit this case as still another proof of the ruggedness of DuMont equipment. It is certainly reassuring when you face extra-severe service conditions. Likewise indicative of years of trouble-free life.

► DuMont cathode-ray tubes and oscillographs in both standard and special types are found in many branches of the armed forces; in many industries engaged in war and civilian production; in engineering and research activities.

Be sure you have our new catalog and manual just off the press, in your working library. Otherwise write for your copy. And submit any unusual problems for our engineering collaboration, recommendations, specifications, quotations.

DUMONT

**ALLEN B. DU MONT
LABORATORIES, Inc.**

Passaic • New Jersey
Cable Address: Wespexlin, New York





Helping the tire maker: Pictured here is a laboratory model of the new Westinghouse-developed "mass spectrometer," an adaptation of which analyzes gases with incredible swiftness and accuracy. Right now, one of the most important of its many uses is speeding up tremendously a step in the making of synthetic rubber.

Westinghouse research accepts every wartime challenge . . .

Under the spur of war, Westinghouse research is delving into numberless mysteries, not only in the vast field of electricity and electronics, but also in chemistry, physics, metallurgy, plastics. And as a result, out of the great Westinghouse laboratories has come a steady stream of new war products, and new and better ways of making old ones.

Westinghouse research develops new talent for America . . .

To Westinghouse, each year, come several hundred budding scientists and engineers—to work, to learn, to blaze new trails in electrical research. And each year, through more than 100 Westinghouse scholarships, young men enter America's engineering colleges to develop the native skill and talent that have made America great and will make it greater.



Westinghouse research promises new wonders for peace . . .

You have heard much talk of the marvels science will offer you after the War. Well, there *will* be marvels—plenty of them—and Westinghouse research is working to contribute its full share. But we will never lose sight of what we consider our first duty: seeing that, beyond all question, each Westinghouse product, old or new, is the very finest of its kind. Westinghouse Electric & Manufacturing Co., Pittsburgh, Pennsylvania. Plants in 25 cities, offices everywhere.





MYCALEX
THE INSULATOR

"...is the most nearly perfect electrical insulator known today"

—an opinion subscribed to by leading engineers in radio, television and industry.

U. S. NAVY OFFICIAL PHOTO

THERE IS ONLY ONE MYCALEX

Adaptability in any climate . . . adaptability in the number of methods in which it may be utilized . . . adaptability in every way—this is the characteristic quality of MYCALEX. Since its introduction twenty-five years ago, the capacity to "work" where performance and efficiency are the major requirements has made the name MYCALEX synonymous with insulation.

Extremely versatile in application, MYCALEX can be cut, drilled, tapped, machined, ground, and polished . . . and if you have a special job where moulded parts are needed, your specifications are invited. Moreover, MYCALEX meets all standards for close

tolerances. It has a low power factor, low loss, negligible moisture absorption, and high dielectric strength . . . and it is leadless. Summing up, MYCALEX may be considered as superior to other types of glass-bound mica insulation. In the words of respected engineers, it's the "most nearly perfect electrical insulator known today."

Remember—MYCALEX is not the name of a class of materials, but the registered trade-name for low-loss insulation manufactured in the Western Hemisphere by the *Mycalex Corporation of America*. Sheets and rods immediately available for fabrication by us or in your own plant.



Trade Mark Reg. U. S. Pat. Off.

BACK THE ATTACK . . . BUY MORE WAR BONDS

MYCALEX CORPORATION OF AMERICA

Exclusive Licensee Under All Patents of MYCALEX (PARENT) CO., Ltd.

60 CLIFTON BOULEVARD

CLIFTON, NEW JERSEY

WHERE ELSE CAN YOU BUY THIS?



Usually, you can't buy experience in packages. And we never heard of "know-how" being sold by the cubic yard. But when you place your electron tube parts and machinery requirements with RCA, you are buying much more than the product your receiving department stacks on the platform.

Actually, you get over a decade of experience in a highly specialized field—experience that cannot be duplicated anywhere else in the tube industry.

The RCA Tube Parts and Equipment Department has been at the service of the industry for the past 12 years. This organization exists today because of *your cooperation and your confidence* in its ability to do a job for you. Your present confidence is our most important obligation—your continued cooperation our principal objective.



RCA TUBE PARTS AND MACHINERY
RADIO CORPORATION OF AMERICA
RCA VICTOR DIVISION **HARRISON, N. J.**

1943

ARMY

E

NAVY



THE WAR DEPARTMENT OF
THE UNITED STATES OF AMERICA
RECOGNIZES IN THIS AWARD FOR DISTINGUISHED SERVICE
THE LOYALTY, ENERGY AND EFFICIENCY IN THE PERFORMANCE
OF THE WAR WORK BY WHICH

National Co.

AIDED MATERIALLY IN OBTAINING VICTORY FOR THE ARMS
OF THE UNITED STATES OF AMERICA IN THE WAR WITH
THE IMPERIAL GERMAN GOVERNMENT AND THE IMPERIAL
AND ROYAL AUSTRO-HUNGARIAN GOVERNMENT

1918

The men and women of National Company take great pride in the reception of the Army-Navy "E" Award for excellence in production. To us it brings a special satisfaction, for twenty-five years ago we received a similar award for service to the Nation in World War I. Old timers have set the pace in winning both awards, but new hands have joined with old skills in putting our difficult job across. It is our pride and our pledge that we of National Company shall keep our record of service bright.

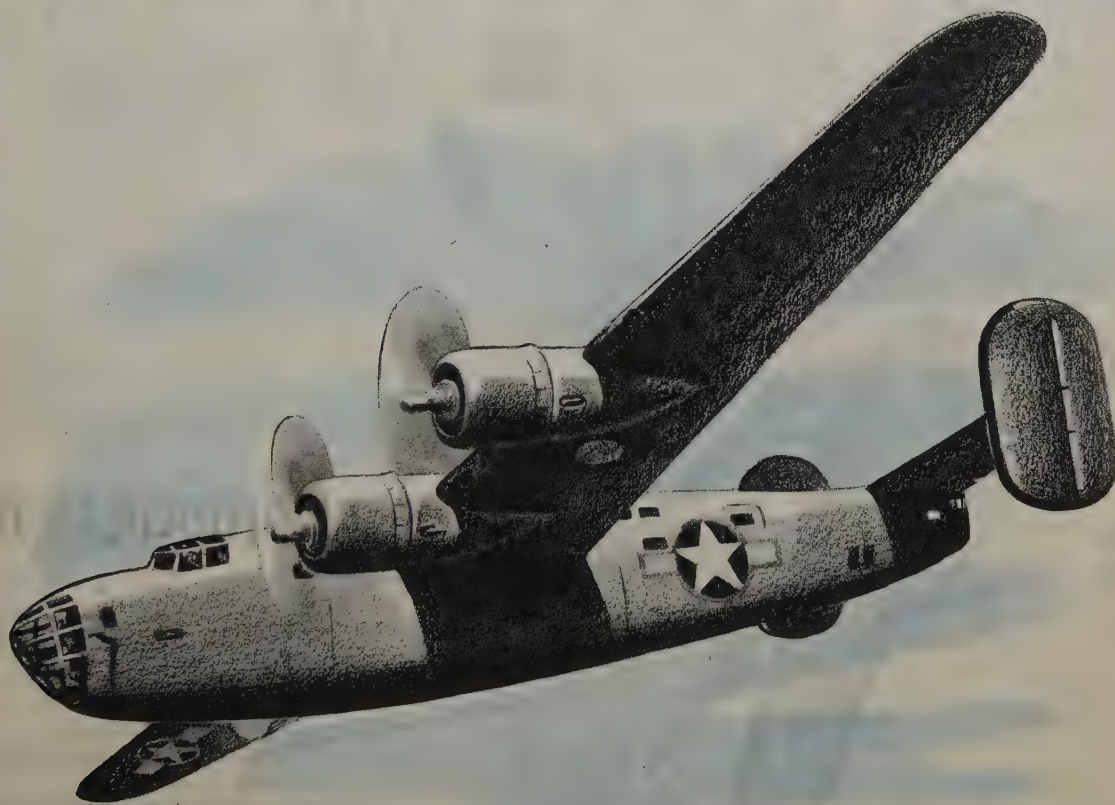


NATIONAL COMPANY, INC.

MALDEN, MASS., U. S. A.



FOR LIBERTY'S SAKE...



WILCOX ELECTRIC COMPANY

Manufacturers of Radio Equipment

14th & Chestnut ☆ Kansas City, Mo.

Our Liberators are winging global routes, chartered and uncharted, in the fight to make all men free. Wherever military or civilian planes fly, Wilcox Radio equipment is helping maintain dependable communications.



There's a Christmas rush on telephone wires, too

Help keep war-crowded
circuits clear on December 24,
25 and 26.

Please use Long Distance
only if it is vital.

War needs the wires—even
on holidays.

BELL TELEPHONE SYSTEM



ANSWER

To an Engineer's Prayer



WHEN WAR began, among products high on the "critically needed" list were N. U. power tubes. To operate thousands of field and ship transmitters, these tubes were needed in quantities which called for vastly increased facilities *plus some entirely new thinking along mass production lines.*

With a thoroughness that could not miss, National Union engineers went to work on this assignment. Soon they not only had the increased volume required—but in addition we had found the answer which many a tube engineer and production man had long sought, even prayed for...

the Tube Industry's first automatic exhaust and sealing machines to operate successfully with this type of tube.

Such resourcefulness and engineering capacity have played no small part in making National Union one of the Tube Industry's largest producers of war goods. For improved types of tubes and installation data to keep their post-war business in step with electronics progress, service engineers can *count on* National Union.

National Union Radio Corporation, Newark, N. J.

*Factories at Newark, N. J.; Maplewood, N. J. -
Lansdale, Penna.; Robeson, Penna.*



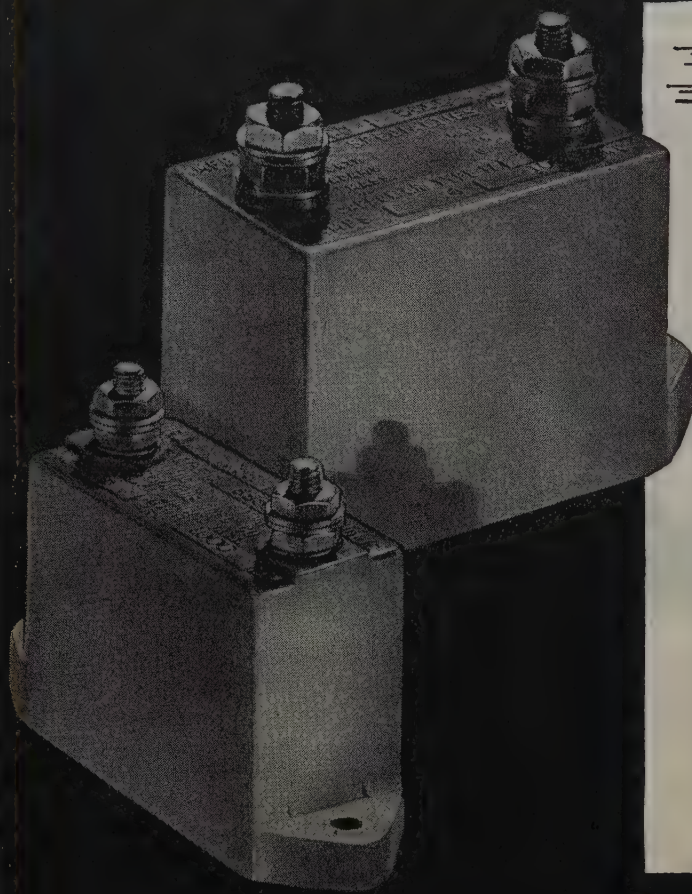
NATIONAL UNION

RADIO AND ELECTRONIC TUBES

Transmitting, Cathode Ray, Receiving, Special Purpose Tubes • Condensers • Volume Controls • Photo Electric Cells • Panel Lamps • Flashlight Bulbs

MOLDED-CASE POTTED MICA CAPACITORS

Made to American War Standard Specifications

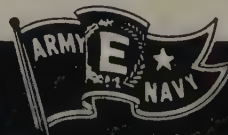


fast deliveries

Need medium-power mica transmitting-type Capacitors to match today's exacting specifications? Then write for details—or samples—on Types CM-65 (Sprague MX-16) and CM-70 (Sprague MX-17). These sturdy units are specifically designed to meet American War Standard requirements for Capacitors of this type and, as of the date this message is written, deliveries are surprisingly prompt, thanks to Sprague's greatly increased plant capacity.

SPRAGUE SPECIALTIES CO.

NORTH ADAMS, MASS.



SPRAGUE

CAPACITORS

KOOLOHM RESISTORS

Instruments of Control



In important broadcasting stations, both here and abroad... in major motion picture and sound recording studios... in leading scientific and industrial laboratories the dominant note is control. Wherever dependable control is a necessity, DAVEN attenuators are the choice of discerning engineers. Precise DAVEN instruments meet every requirement of accuracy... dependability... serviceability.

DAVEN produces the most complete line of precision attenuators in the world... plus more than 80 models of laboratory test equipment for the broadcast, sound picture, television and electrical fields. A DAVEN catalog should be in your files.

THE DAVEN COMPANY

191 CENTRAL AVENUE

NEWARK 4, NEW JERSEY

HELP BRING VICTORY ONE DAY CLOSER... BUY AN EXTRA WAR BOND TODAY






TEST ASSIGNMENT

ECA has along with other manufacturers, been assigned a number of specialized tasks in the war effort. One of these is the production of test equipment for air fighters. This assignment is being fulfilled with a knowledge growing out of more than 20 years of diversified radio and electronic techniques.

During these years, most of our executives and personnel have functioned as one unit. We've worked together, experimented together, learned together. Accordingly, ECA assignments have been, still are, and will be delivered as promised . . . to your fullest satisfaction. 100% in war work . . . occasionally, however, production schedules enable us to accept additional contracts.

BE A BLOOD DONOR

On some far-off battlefield a soldier lies wounded. Perhaps he's your boy or the son of a neighbor. A pint of blood . . . just one pint of blood . . . may mean the difference between life and death. You can render no finer service to America than to donate a pint of your blood regularly to the Red Cross.



ELECTRONIC CORP. OF AMERICA

45 WEST 18th STREET • NEW YORK 11, N.Y. • WATKINS 9-1870

An Award and An Acknowledgment



The Employees of The Rola Company Inc., now wearers of the Army-Navy "E", wish to acknowledge a debt...and express a word of appreciation...to certain people outside the Rola organization. They are far too numerous to mention by name but they include:



The Personnel of the Army and Navy Air Forces with whom we have worked.



The Prime Contractors who have entrusted us with orders.



The Suppliers of our equipment and materials.



The Transportation Companies who have handled our shipments.



The many others on whom we have had to depend.

To all those at home who have *helped* us, and to our former associates, now in the armed services, who have *inspired* us, we express our deep gratitude...and with them we proudly share the honor of this Award. The Employees of THE ROLA COMPANY INC., Cleveland, Ohio.

ROLA

MAKERS OF THE FINEST IN SOUND REPRODUCING AND ELECTRONIC EQUIPMENT



NOT HERE, Hirohito!

● So sorry, son of heaven, but the answer is "NO! You can't land here!" . . . Not with these gallant little sluggers, the PT boats, on the job. They're tough. They're fast. They never sleep. And whatever the occasion demands, they've got what it takes.

As a concentrated package of poison for the Axis, the PT boats are an outstanding example of the way American engineers, workers and manage-

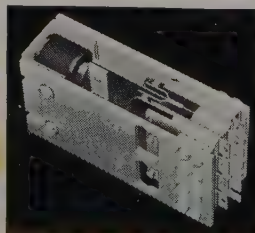
ment are teaming together to produce the deadliest weapons the world has ever known. And naturally, we're proud that *E·L* equipment is giving a good account of itself on PT boats.

The widespread use of *E·L* Vibrator Power Supplies as standard equipment—on land, sea and air—for radio, lighting, communications, etc.—wherever electric current must be changed in voltage, frequency or type—is evidence of the efficiency and rugged dependability of *E·L* products.



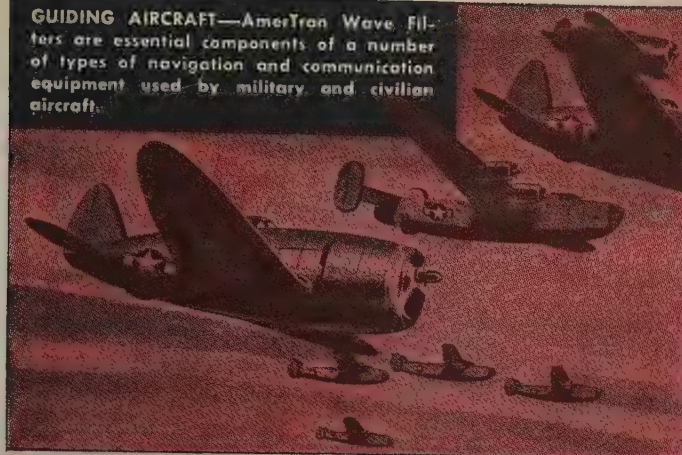
Electronic
LABORATORIES, INC.
INDIANAPOLIS

E·L ELECTRICAL PRODUCTS —Vibrator Power Supplies for Communications . . . Lighting . . . Electric Motor Operation . . . Electric, Electronic and other Equipment . . . on Land, Sea or in the Air.

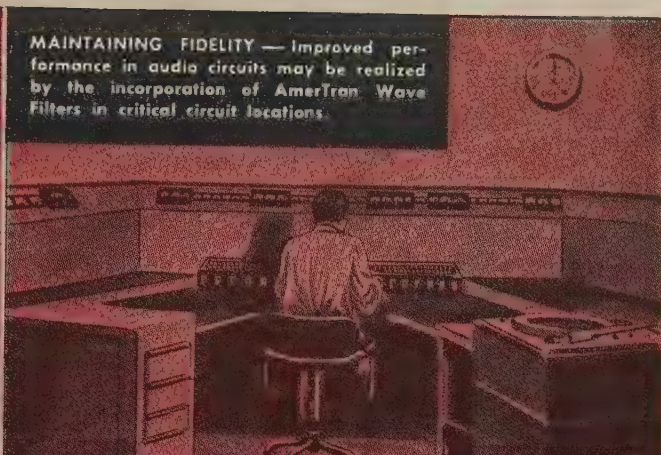


E·L Tandem Type Vibrator —
For changing DC to AC in Vibrator Power Supplies. Delivers as much as 750 watts DC or AC. Input Voltage: 4-220 volts; Input Wattage Rating (max.): 125-1000 watts, depending upon input voltage; Frequencies: 60, 100, 120 standard; 20-120 available range; effective life: 1500 hrs.

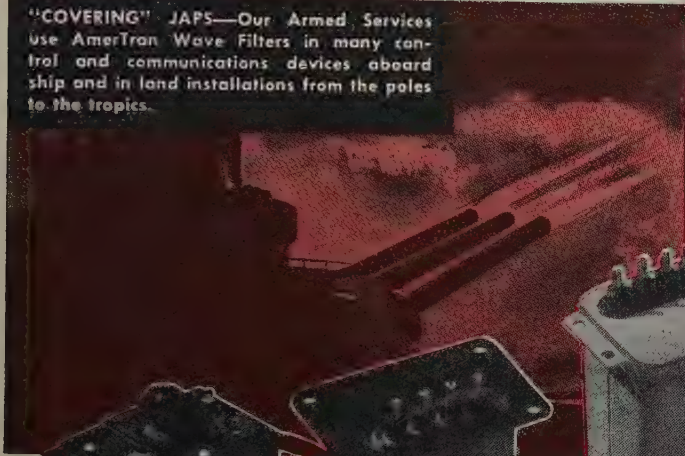
GUIDING AIRCRAFT—AmerTran Wave Filters are essential components of a number of types of navigation and communication equipment used by military and civilian aircraft.



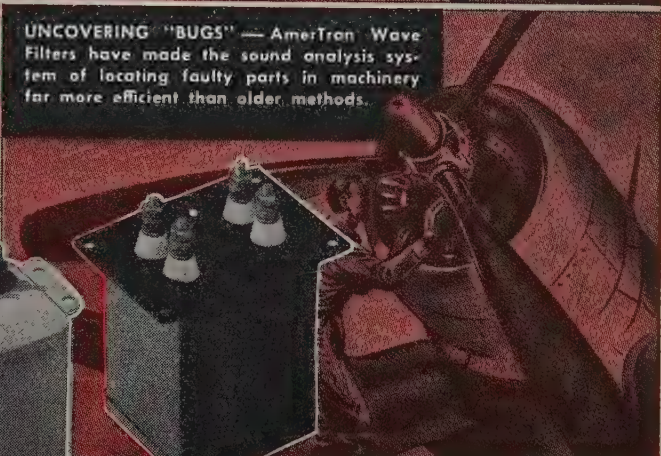
MAINTAINING FIDELITY—Improved performance in audio circuits may be realized by the incorporation of AmerTran Wave Filters in critical circuit locations.



"COVERING" JAPS—Our Armed Services use AmerTran Wave Filters in many control and communications devices aboard ship and in land installations from the poles to the tropics.



UNCOVERING "BUGS"—AmerTran Wave Filters have made the sound analysis system of locating faulty parts in machinery far more efficient than older methods.



• • • • FOR ALL TYPES OF PRECISION CONTROL EMBODYING FREQUENCY DISCRIMINATION

THE increasing use of AmerTran Wave Filters in precision control apparatus involving frequency discrimination is due to their uniformity, accuracy, low loss ratio and minimum distortion. Compact, rugged, impervious to climatic conditions, they serve on widely varying fronts. Comprising High Pass, Low Pass, Band Pass, Band Rejection, Combinations and Equalizers, AmerTran Wave Filters have a wide variety of applications.

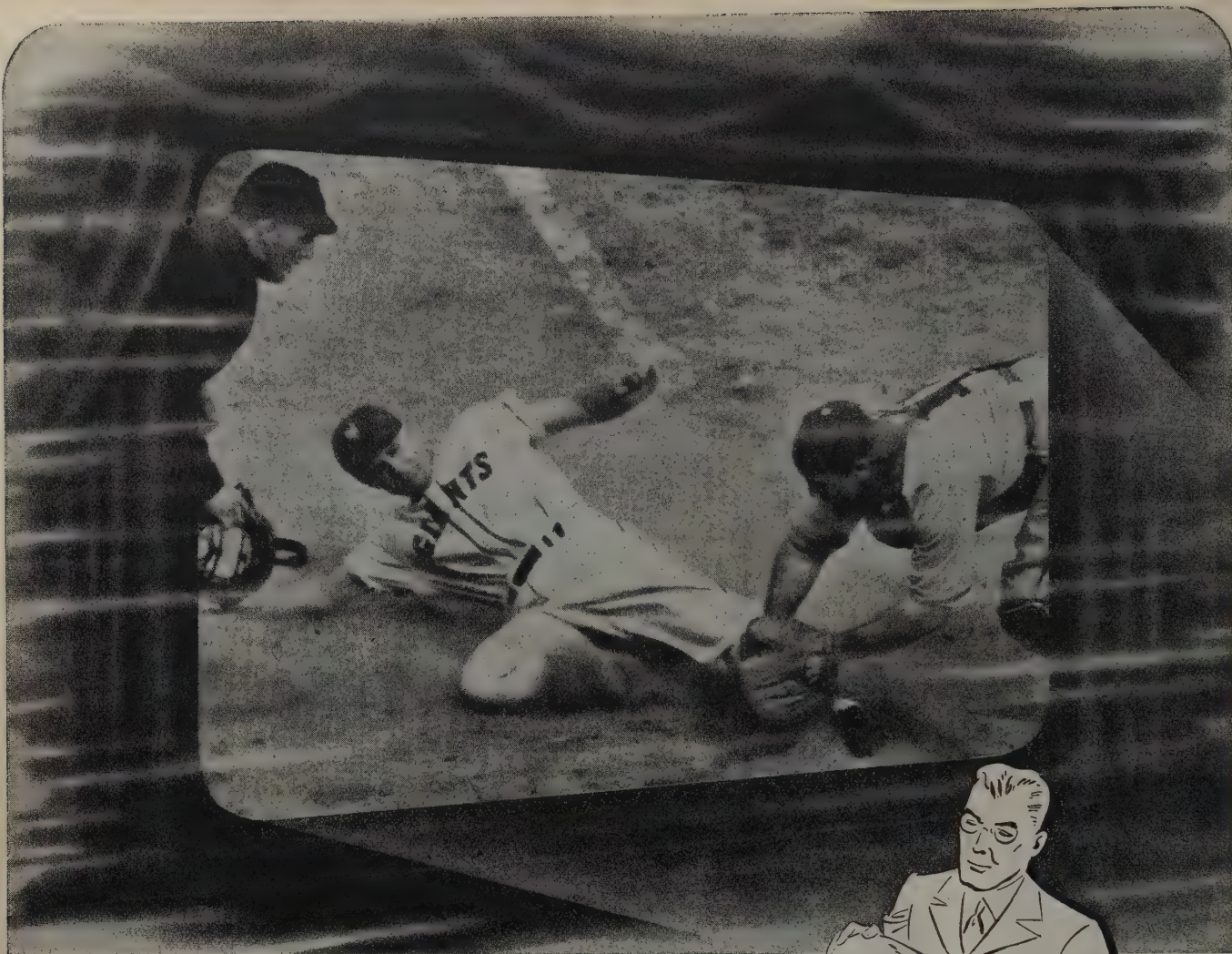
While AmerTran Wave Filters are restricted to war equipment today, we invite inquiries regarding post-war applications.

AMERICAN TRANSFORMER COMPANY
178 Emmet Street, Newark, New Jersey

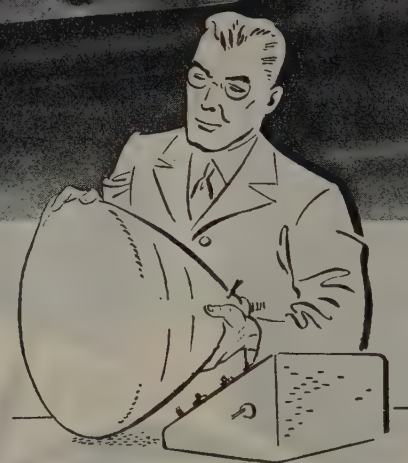
AMER-TRAN
Pioneer Manufacturers of
Transformers, Reactors
and Rectifiers for
Electronics and
Power Transmission

AMERTRAN

MANUFACTURING SINCE 1901 AT NEWARK, N.J.



The vision in Television



To the research mind, day dreams are an important part of scientific achievement. *Vision* and ceaseless work on the part of RAULAND scientists and engineers, for example, brought the cathode ray tube, heart of television, to its present perfected state. As a result, television can today be projected on theatre screens with a clarity and definition comparable to that of regular film showings.

★ Modern applications of electronics are so vast in scope and require such delicate variations in size and power of the actuating tubes that the RAULAND organization devotes its facilities, not to *mass production*, but to *custom engineering* . . . producing tubes and other electronic instruments of specific design and capacity to fulfill the tasks each are called upon to do.

It is the meeting of vision, precise engineering and facilities for producing that combine in the RAULAND term Electroneering.

RADIO . . . SOUND . . .

Rauland

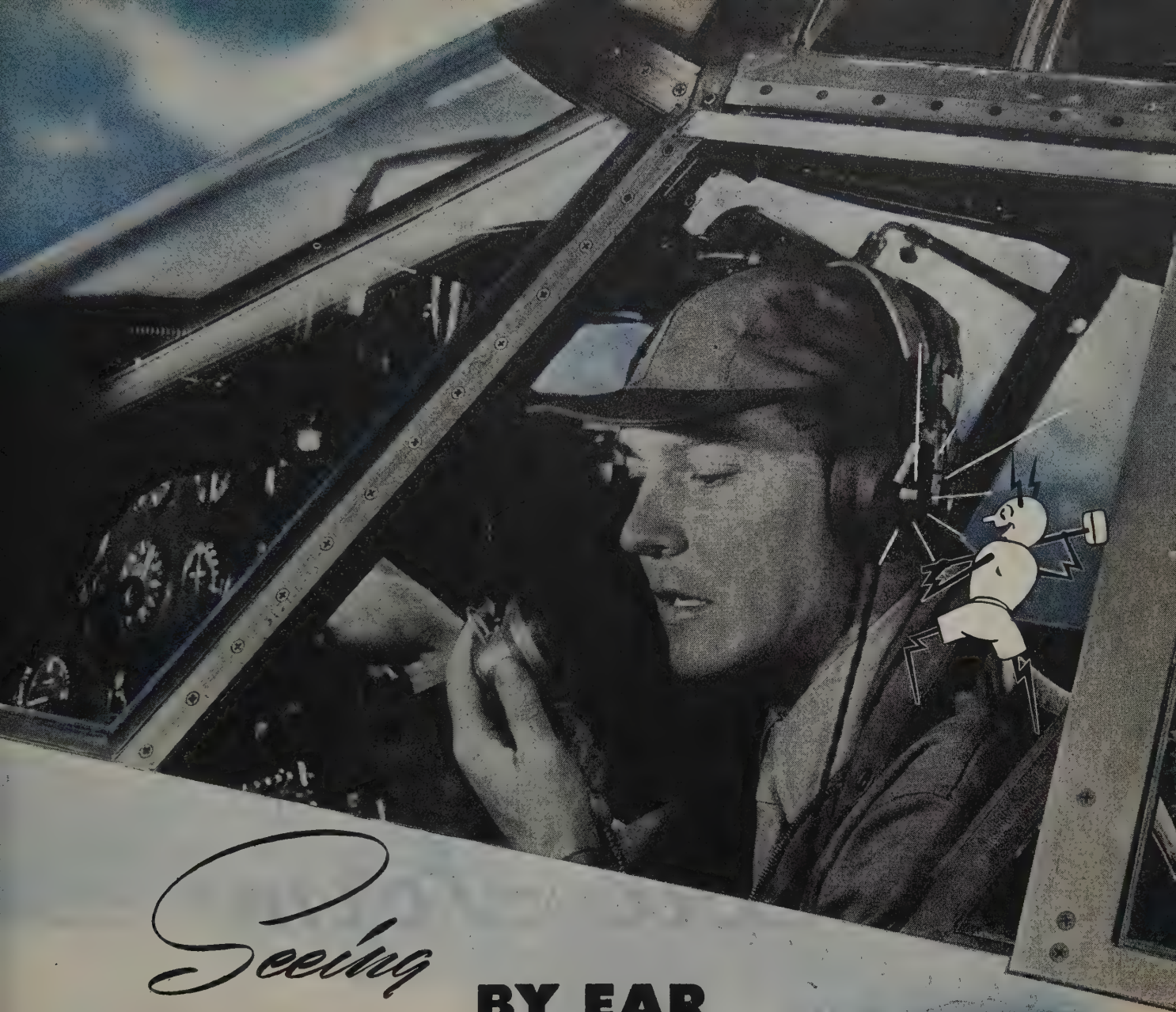
. . . COMMUNICATIONS

Electroneering is our business

THE RAULAND CORPORATION . . . CHICAGO, ILLINOIS

Rauland employees are still investing 10% of their salaries in War Bonds



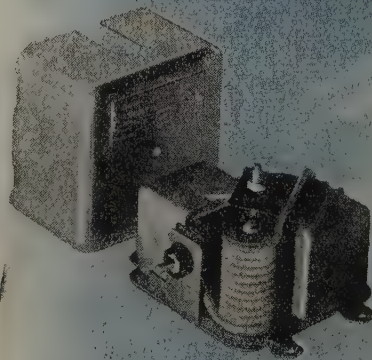


Seeing ...BY EAR

A fighting man must fly blind sometimes, but deaf never. In long range bombers . . . in scrappy pursuit planes . . . whatever the visibility, vital communication channels must be kept clear. Unless the proper suppression filter system is installed, noisy radio interference acts like a pack of demons . . . sabotages communications upon which the safety of men and their military missions depend.

Solar Elim-O-Stats are Communications' Life-savers. They are compact filters which protect against local static, absorbing it *right where it starts*—at generators, motors, contacts, and other sources. Solar Capacitors are reliable components used by practically all leading manufacturers of military radio equipment. From command car to jeep or tank . . . from ship to ship or plane . . . between planes—wherever radio is vital—Solar Capacitors and Elim-O-Stats help keep channels clear, so fighting men can hear.

If you have a problem concerning capacitors or radio noise suppression, call on Solar Manufacturing Corporation, 285 Madison Ave., New York 17, N. Y.



Solar

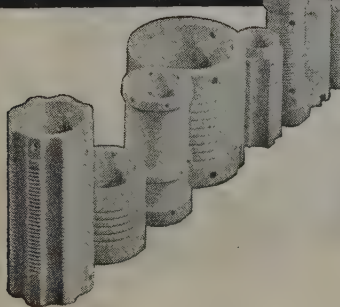
SOLAR ELIM-O-STATS

CAPACITORS AND RADIO NOISE-SUPPRESSION FILTERS

STUPAKOFF

FOUNDED IN 1897

Ceramics for the World of Electronics



Coil Forms

PRECISION MADE . . . of Steatite and other materials—glazed or unglazed—any size or shape—to your exacting specifications.



Years of experience—wide technical and engineering knowledge—modern manufacturing facilities enable STUPAKOFF to produce every type of ceramic for the electronic industry.

Back The Attack—With War Bonds

STUPAKOFF CERAMIC AND MANUFACTURING CO., LATROBE, PA.

WHY



One of a series
showing
AMPEREX tubes
in the making

AMPEREX

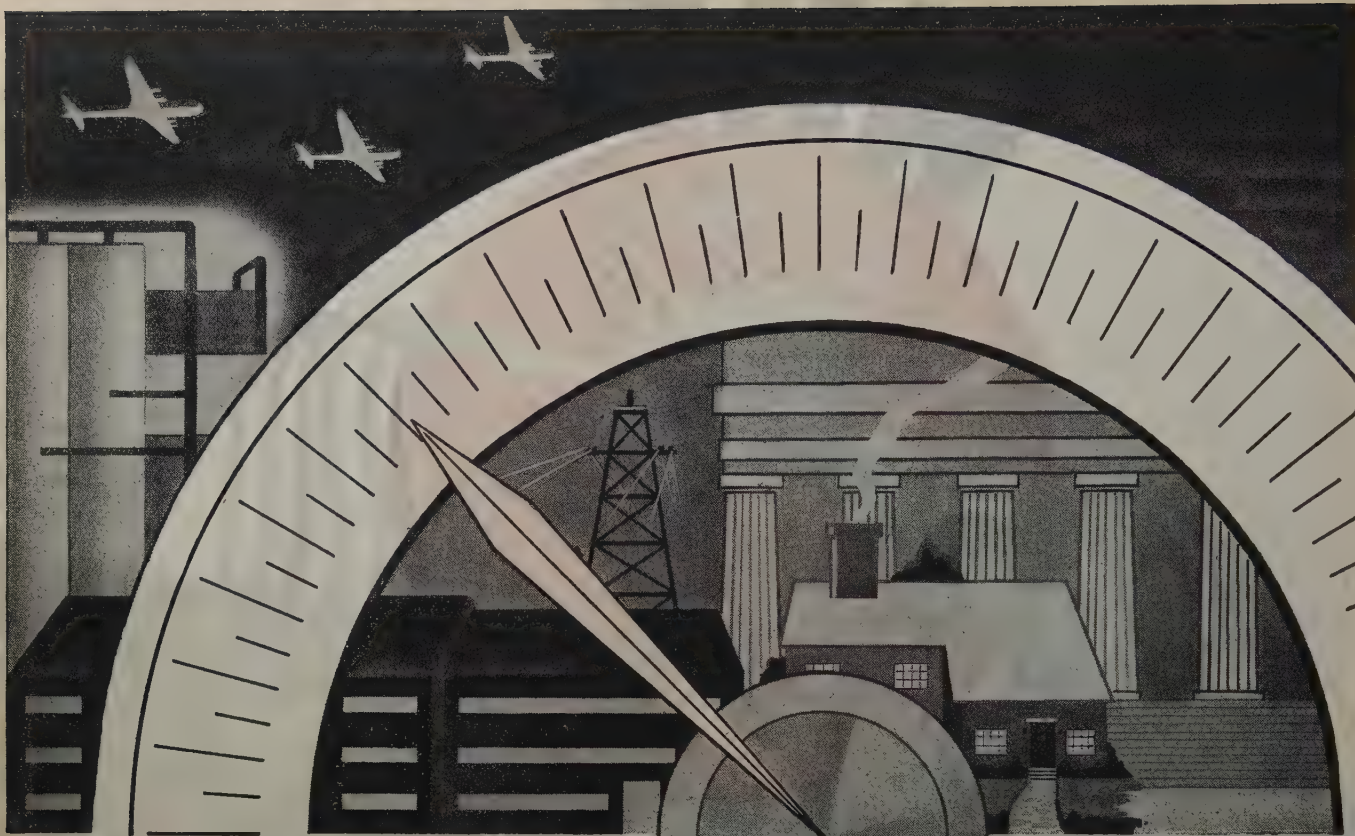
**WATER AND AIR COOLED
TRANSMITTING AND RECTIFYING TUBES**

Amperex is a scientific laboratory, on an enlarged scale, where rare and refractory metals, materials and gases are processed and combined into precise and delicate instruments. The meticulous construction of each tube is supplemented by a series of tough, pre-shipping tests. You receive a perfect product, fortified with the "Amperextras" which assure longevity, uniformity and dependability. All Amperex tubes may be interchanged with your present tubes without circuit readjustment.



GIVE A PINT OF BLOOD TODAY . . . SAVE SOME SOLDIER'S LIFE TOMORROW

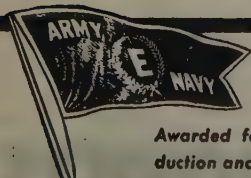
AMPEREX ELECTRONIC PRODUCTS
79 WASHINGTON STREET • BROOKLYN 1, N. Y.



THE ACCURATE WAY

**Insure a Better
Postwar World
by Buying More
War Bonds Today**

There is only one way to take a measurement . . . and that is the accurate way. In military, industrial, public service and home front applications, DeJur precision meters have proven themselves to be trustworthy instruments of measurement and control. Illustrated is an example of the many types of DeJur meters . . . specifications for individual requirements are invited.



Awarded for Excellence in Production and Quality of Material

De Jur-Amsco Corporation
SHELTON, CONNECTICUT

NEW YORK PLANT: 99 Hudson Street, New York City

CANADIAN SALES OFFICE: 560 King Street West, Toronto



THE IMPERISHABLE QUALITY OF A GEM

PRIDE of craftsmanship which produced the exquisite steatite cameos and intaglios of the ancient Greeks and Romans lives today in the fine workmanship, characteristic of **ALSiMAG** Steatite Ceramic insulators for electronic uses.

And the imperishable qualities of those ancient steatite gems that have survived thousands of years are present in greater measure in **ALSiMAG** Steatite Ceramics.

ous to heat up to 1000°C...insulating qualities unimpaired even with arc-overs...impervious to moisture...**ALSiMAG** Steatite Ceramics perform in a manner impossible of perishable organic materials.

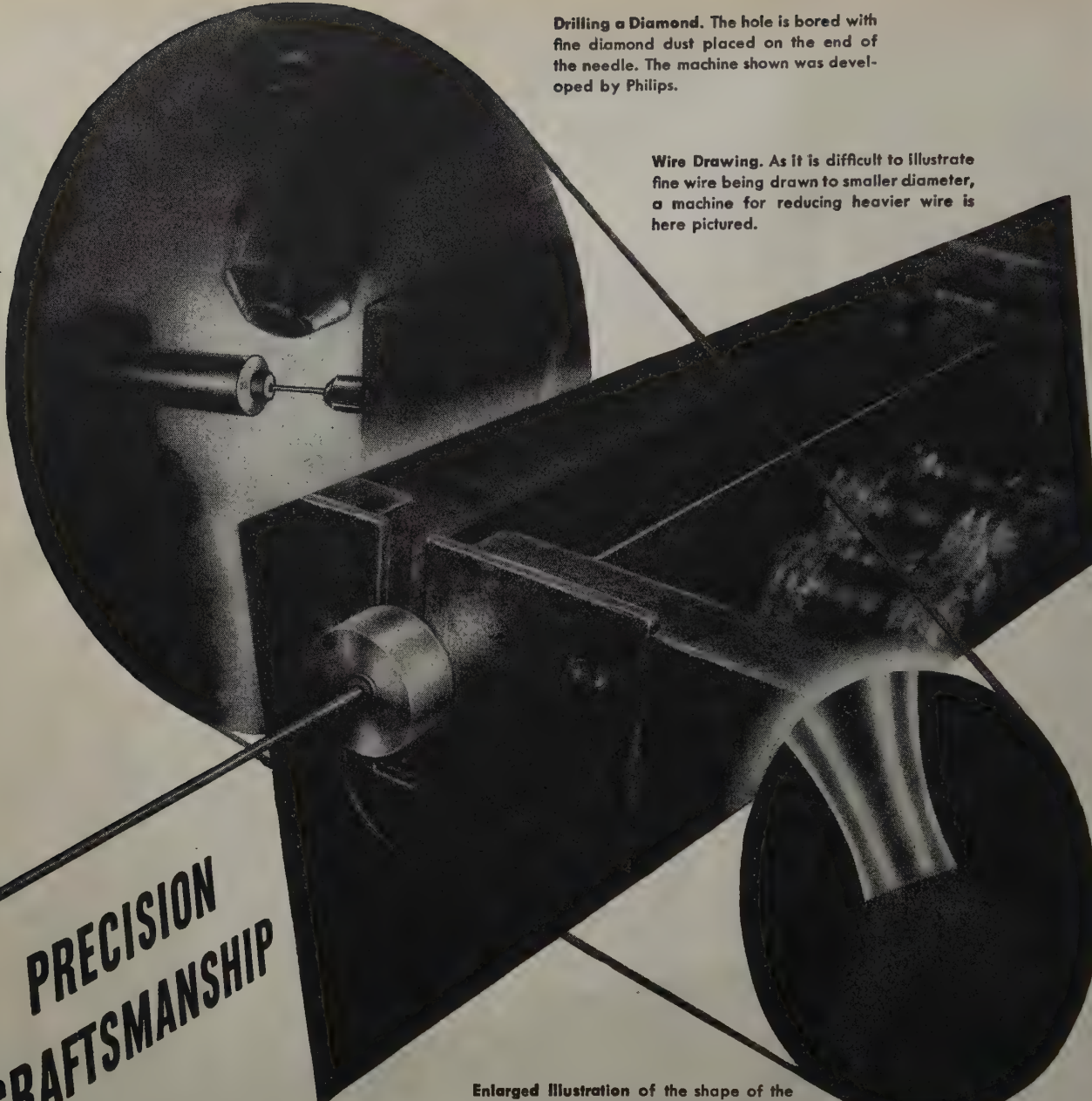
....

ALSiMAG is produced in a variety of bodies with electrical properties to fit your requirements. Our Research and Engineering staff will gladly cooperate in designing Steatite Ceramic insulation for economy in

ALSiMAG
TRADE MARK REGISTERED U. S. PATENT OFFICE

STEATITE CERAMIC ELECTRICAL INSULATION
FOR ELECTRONIC USES

AMERICAN LAVA CORPORATION



Drilling a Diamond. The hole is bored with fine diamond dust placed on the end of the needle. The machine shown was developed by Philips.

Wire Drawing. As it is difficult to illustrate fine wire being drawn to smaller diameter, a machine for reducing heavier wire is here pictured.

**PRECISION
CRAFTSMANSHIP**

Enlarged Illustration of the shape of the hole through the Diamond Die. Unless the hole is correctly shaped for the material, the wire will break when it is drawn through the die.

Precision manufacture by North American Philips is exemplified in the Diamond Die and Wire Drawing Divisions. Machines both for making diamond dies down to .0005 of an inch and drawing wire to that diameter are Philips developments.

The tiny hole drilled through the diamond to make the die not only must be exactly the diameter specified, but it must have a smooth, cone-shaped opening, as illustrated. The operation may take weeks. The drilling is under constant inspection for accuracy through a powerful microscope.

This example of precision craftsmanship is but one of many in the wide background of research and development of our engineers.

Today this knowledge is being used to hasten Victory; tomorrow it will be available to aid Industry.

For our Armed Forces we make Quartz Oscillator Plates; Amplifier, Transmitting, Rectifier and Cathode Ray Tubes for land, sea and air-borne communications equipment.

For our war industries we make Searchray (X-Ray) apparatus for industrial and research applications; X-Ray Diffraction Apparatus; Electronic Temperature Indicators; Direct Reading

Frequency Meters; Tungsten and Molybdenum in powder, rod, wire and sheet form; Tungsten Alloys; Fine Wire of practically all drawable metals and alloys: bare, plated and enameled; Diamond Dies; High Frequency Heating Equipment.

And for Victory we say: Buy More War Bonds.

Norelco

**ELECTRONIC PRODUCTS by
NORTH AMERICAN PHILIPS COMPANY, INC.**

Executive Offices: 100 East 42nd Street

New York 17, New York

Main factory in Dobbs Ferry, New York; other factories at Lewiston, Maine (Elmet Division); Mount Vernon, N. Y. (Philips Metalix Corp.)



keeps its Shape

New and more exacting problems in insulation are being solved by MYKROY, the perfect low-loss, glass-bound mica insulating material.

One of the many outstanding *mechanical* properties of MYKROY is that it will not warp, shrink or change its physical form under adverse conditions of heat, cold or humidity.

Equipment insulated with MYKROY functions with dependable efficiency in torrid jungles, polar regions, vapor-laden chemical plants . . . at sea and under the sea.

From Reports of Independent Testing Laboratories

No. 4		No. 8
6.68.....	Dielectric Constant (Dry).....	6.75
6.73.....	Dielectric Constant (Wet).....	6.70
.00240.....	Power Factor (Dry).....	.00164
.00241.....	Power Factor (Wet).....	.00231
1.60.....	Loss Factor (Dry).....	1.11
1.62.....	Loss Factor (Wet).....	1.54
630 Volts per Mil.....	Dielectric Strength.....	660 Volts per Mil.

VASTLY INCREASED FACILITIES TO FILL YOUR ORDERS PROMPTLY

No more delays or bottlenecks! Increases of more than 400% in our plant and personnel now afford ample capacity to handle largest orders. We are equipped to mold or machine any type or volume of component parts to your specifications. Our specialized engineering knowledge is at your service.

Write for complete engineering data and ratings. Talk over your insulating problems with our specialists.

MYKROY IS SUPPLIED IN SHEETS AND RODS . . . MACHINED OR MOLDED TO SPECIFICATIONS

MADE EXCLUSIVELY BY **ELECTRONIC MECHANICS** INC.

70 CLIFTON BOULEVARD • CLIFTON, NEW JERSEY
Chicago 47; 1917 NO. SPRINGFIELD AVENUE • TEL. Albany 4310

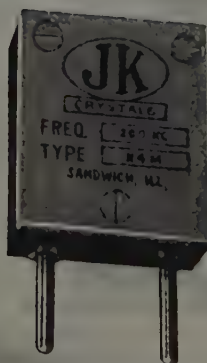
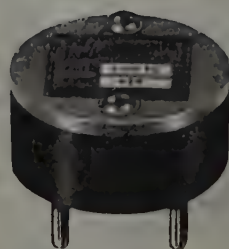
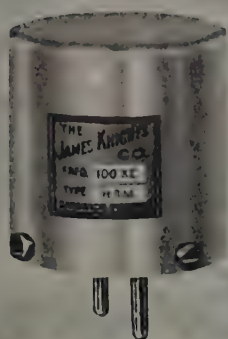
The Home of America's Finest . . .

JAMES

Crystals
KNIGHTS



★ Sandwich, Illinois
(CRYSTAL HEADQUARTERS)



**DO YOU HAVE A
CRYSTAL PROBLEM?**

For years, we have specialized in the quantity production of an exceptionally wide variety of quality Quartz Crystals. Recent patents granted to us on new precision cuts and improved mechanical processes have increased still further the accuracy and volume output of James Knights Crystals. We make samples nearly every day for some new customer so that he can design his equipment to fit a crystal that is now a standard of comparison. Why not let us help you?

**PRECISION CUTTERS OF QUARTZ
for
COMMUNICATIONS & OPTICAL USES**

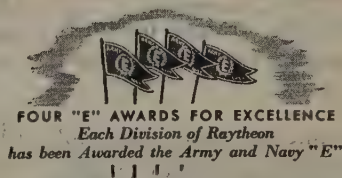
The JAMES KNIGHTS Company
SANDWICH, ILLINOIS PHONE 65

Don't lie awake nights . . .

. . . worrying about the countless intricacies involved in the design of new electronic devices. Don't worry, that is, unless you also are planning to use the best electronic tubes. For, just as a bridge must be strong enough to meet all the demands of the traffic it is intended to carry—so electronic tubes must be carefully chosen to perform perfectly. Raytheons are engineered to meet the most rigid requirements.



RAYTHEON TUBES, long known and respected by manufacturer and radio servicemen alike, are being specified more and more by advanced electronic engineers and designers whose vital projects demand the finest in tubes.



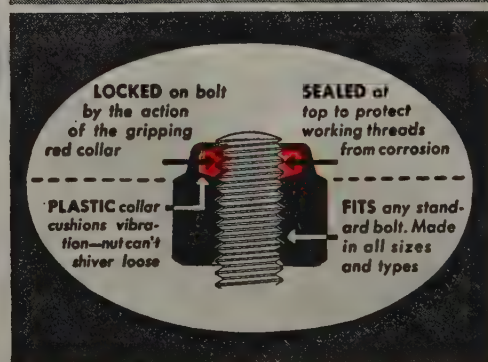
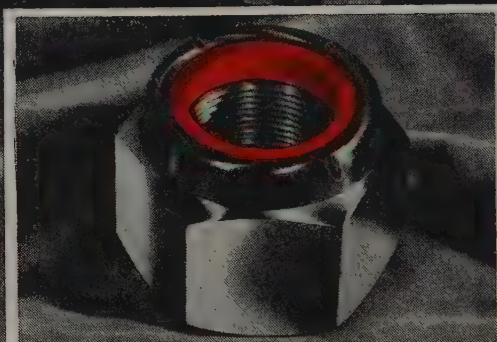
RAYTHEON

RAYTHEON MANUFACTURING COMPANY
Waltham and Newton, Massachusetts


DEVOTED TO RESEARCH AND THE MANUFACTURE OF TUBES AND EQUIPMENT FOR THE NEW ERA OF ELECTRONICS



1. One of the four Elastic Stop Nuts which fasten the 2000-horsepower engine onto the Republic P-47 Thunderbolt.
2. Four more Elastic Stop Nuts hold the fastenings of the wing. Two are shown here.



You've gotta hang on when you say "Giddap" to 2,000 horses

 When the pilot of a Republic P-47 pours on the soup, 2,000 surging, throbbing horsepower yank him into the high blue heavens.

When he climbs straight up he is literally hanging on his prop and engine.

And those tons of plane, man and armament hold onto that engine with just four Elastic Stop Nuts.

This is the kind of job that has given Elastic Stop Nuts the reputation of having revolutionized modern aircraft construction. It's the reason you find over 12,000 of them on the P-47 and as many as 50,000 on some types of bombers.

It's all because these nuts hold fast — without auxiliary locking devices. They're applied like ordinary nuts. They can be removed and replaced time and again without losing locking effectiveness. They stay put, and nothing, even violent vibration, shakes them loose.

It's done by the red elastic collar in the top. This collar clings tightly around the bolt threads. It absorbs and cushions vibration from every direction. The nut can't shiver loose — can't turn.

Postwar progress will present countless fastening problems which these nuts will solve. Perhaps you already are studying such problems.

If so, let us know about them. Our engineers will be very glad to help work out a solution and show you how an Elastic Stop Nut will provide a safer, surer, trouble-free fastening.

ELASTIC STOP NUTS

Lock fast to make things last

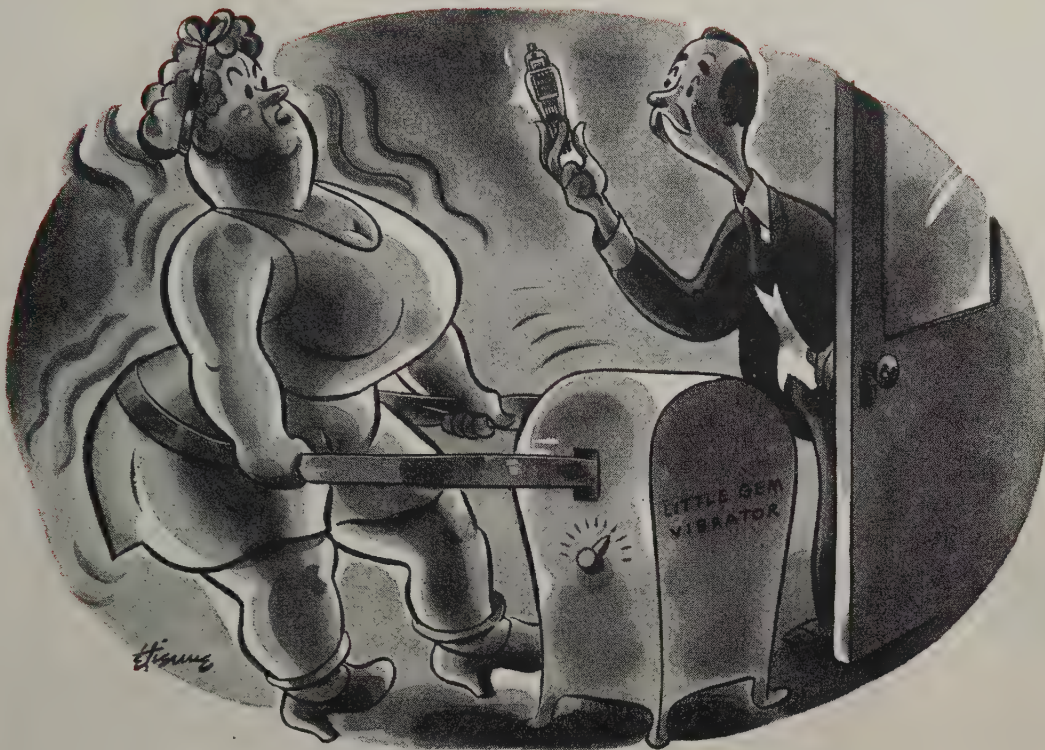


BACK THE ATTACK . . .

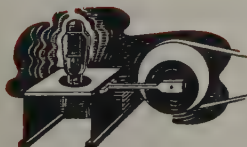
BUY WAR BONDS

ELASTIC STOP NUT CORPORATION OF AMERICA
UNION, NEW JERSEY AND LINCOLN, NEBRASKA

Proceedings of the I.R.E. December, 1943



"We vibrate, 'em, too, Miss Gadfly"



Miss "Tiny" Gadfly, impelled and inspired by the vision of a svelte, girlish figure, oscillates in phase with the vibrations of "Little Gem." With like determination, but with a different scientific purpose, Hytron tubes are also vibrated vigorously.

A motor-driven eccentric arm mercilessly agitates the tube while a sensitive vacuum-tube voltmeter discloses the slightest variation in the a.c. component developed

across the plate load resistor. An imperfect weld—a loose element—a potential short circuit—these, and other trouble-makers are instantly detected.

Tubes which pass this standard Hytron factory test are not likely to fail. When subjected to the ruthless throbbing of machines of war by fighting men too intent on a battle for survival to baby them, these tubes "get the message through."

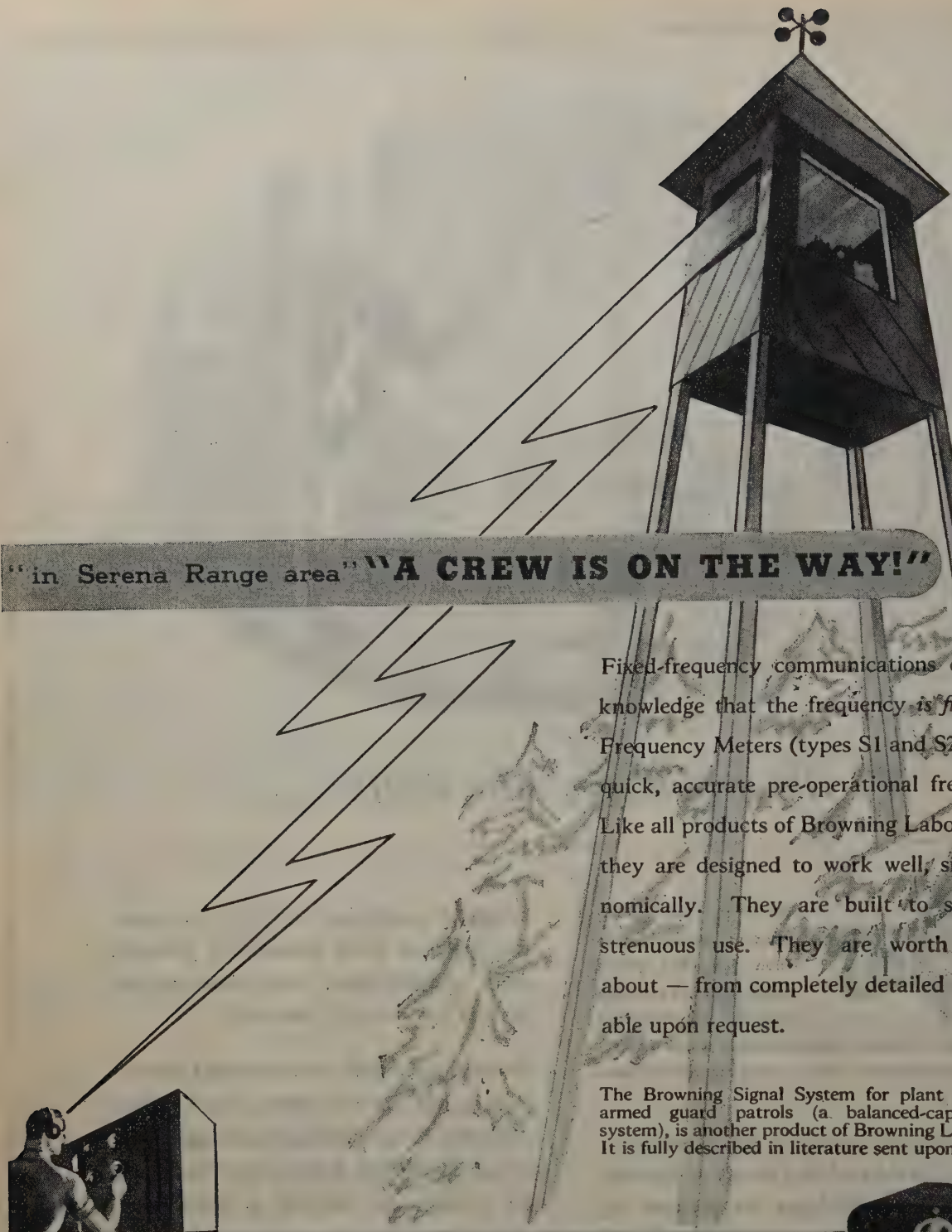
BUY ANOTHER WAR BOND



OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

HYTRON
CORPORATION
ELECTRONIC AND
RADIO TUBES
SALEM AND NEWBURYPORT, MASS.





"in Serena Range area" **"A CREW IS ON THE WAY!"**

Fixed-frequency communications depend on sure knowledge that the frequency is *fixed*. Browning Frequency Meters (types S1 and S2) make possible quick, accurate pre-operational frequency checks. Like all products of Browning Laboratory research, they are designed to work well, simply, and economically. They are built to stand up under strenuous use. They are worth learning more about — from completely detailed literature available upon request.

The Browning Signal System for plant protection without armed guard patrols (a balanced-capacitance electronic system), is another product of Browning Laboratory research. It is fully described in literature sent upon request.



BROWNING

LABORATORIES, INCORPORATED
WORCESTER, MASSACHUSETTS





MICROPHONES—*Under Glass*

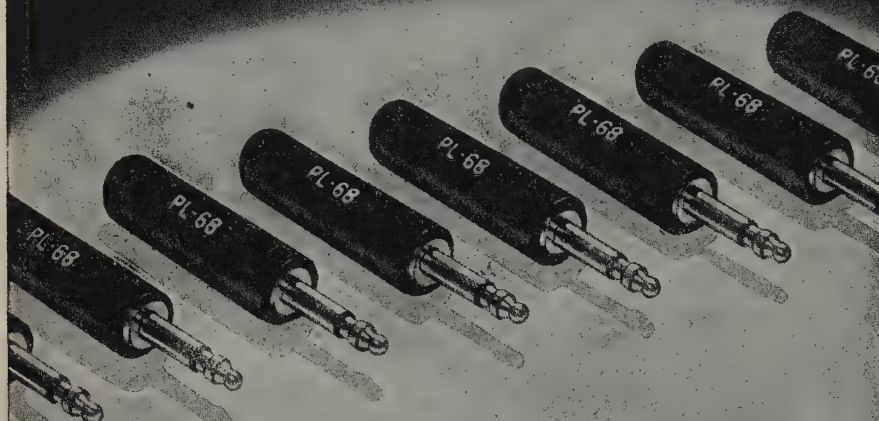
—We call it the room at the plant because that's where we make those very special microphones. But this we can say. New techniques in microphone manufacture involve such extreme care that workers operate in dustproof glass enclosed areas which are air conditioned and humidity controlled. Precision made—they are designed to stand up and perform under extremely difficult combat conditions.



Shure Brothers, 225 W. Huron St., Chicago
Designers and Manufacturers of Microphones and Acoustic Devices

In a Hurry...

70 Types PLUGS & CONNECTORS ARMY SIGNAL CORPS SPECIFICATIONS



**Remler Facilities and Production
Techniques Frequently Permit
Quotations at LOWER PRICES**

Remler made plugs and connectors of the following types are used by more than fifty concerns engaged in manufacturing communications equipment for the U. S. Army Signal Corps:

Types:	PL	PLP	PLQ	PLS
50-A 61 74 114 150	56 65	56 65	56 64	
54 62 76 119 159	59 67	59 67	59 65	
55 63 77 120 160	60 74	60 74	60 74	
56 64 104 124 354	61 76	61 76	61 76	
58 65 108 125	62 77	62 77	62 77	
59 67 109 127	63 104	63 104	63 104	
60 68 112 149	64	64		

Special Designs to Order

Remler Tool and Die, Plastic Molding and Automatic Screw Machine Divisions are equipped to manufacture plugs and connectors of special design in large quantities. Submit specifications.

Wire or telephone if we can be of assistance

REMLER COMPANY, LTD. • 2101 Bryant St. • San Francisco, 10

REMLER

Announcing & Communication Equipment

Manufacturers of Communication Equipment Since 1918



The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No.

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.

330 West 42nd Street, New York 18, N.Y.

ELECTRONIC DESIGN ENGINEERS

One of the largest manufacturers of radio equipment, located in Eastern Massachusetts, has openings for several engineers. Work involves design and development of electronic apparatus having a wide field of application both now and after the war.

A Master's degree, or a B.S. degree in Electrical Engineering with two years' experience in electronic work, would be desirable but not absolutely necessary, depending upon the individual. Those now employed in an essential activity must be able to obtain release. Applicants should submit their qualifications and salary expected to Box 307.

RADIO ENGINEERS AND TECHNICIANS

A progressive company with a sound background in radio and electronics needs, at once, several men with training and experience in any phase of the radio industry. The work open is vital to the war effort but offers a promising post-war future for the right men. College degree or equivalent experience necessary. Men now engaged at highest skill on war production should not apply. Write Box 294.

ELECTRICAL OR CHEMICAL ENGINEER

... thoroughly versed in the theory of liquid and solid dielectrics for the position of chief engineer. To direct the research, development and general laboratory on capacitors and capacitor applications. This is an unusual opportunity for a capable engineer interested in his present and postwar future. Write to Industrial Condenser Corp., 1725 W. North Ave., Chicago, Ill.

RADIO ENGINEERS

Transcontinental & Western Air, Inc. has openings at Kansas City for three Radio Engineers in the Communications Department. Applicants should have completed an electrical or radio engineering course, or should have had one to two years of practical experience. These openings are permanent.

For additional details and application forms, write to Personnel Department, Transcontinental & Western Air, Inc., Kansas City, Missouri.

PATENT ATTORNEYS

Patent attorneys, who are electronic physicists and electrical or radio engineering graduates who have maintained contact with the field of high-frequency electronics, radio manufacture, carrier-current telephony, and light-current circuit design and computing, can make a substantial contribution in research or development jobs with one of the National Defense Research Committee laboratories located in the East. The project is secret but is one of the most urgent of all research jobs now under way for the Government.

An electrical engineering background in light currents is essential, and amateur radio experience, inventive ability and ingenuity in the design and layout of radio equipment would be of considerable help.

Facilities for specialized refresher training and orientation in the particular field may be available. Anyone who possesses these qualifications and is interested in a vital wartime development job for the duration may get further details on request. All inquiries will be held confidential. Address Box 299.

(Continued on page 48A)

NORTH AMERICAN PHILIPS COMPANY, INC.

Has Opportunities for Well Trained, Highly Qualified Electronic Engineers Commercial Engineers

Electronic Engineers — Opportunities exist in the designing, development and manufacturing of electronic products in general, particularly cathode ray, transmitting and special-purpose tubes; communications, electronic and precision test equipment. High calibre men wanted with proven technical ability and a well-balanced background of acoustics, broadcasting, frequency modulation and ultra-high frequencies.

Also an opportunity for a physio-chemist, preferably with electrochemical experience.

Woman with technical knowledge will be considered.

Commercial Engineers—Several are required. Should have a sound technical experience in any one, or a combination of the following fields: communications, special device circuits, quartz crystal and electronic tube applications; quartz crystal and electronic tube manufacturing processes.

Also one man who should have a background as metallurgist or physicist and

preferably some practical experience with x-ray techniques.

Duties of Commercial Engineers will consist largely of personal contact and correspondence with engineering personnel among manufacturers of electrical and communications equipment, also with Government engineers.

We invite applications from men who are planning their post-war future now. Our company is growing fast. It has a splendid war production record. It has a world-wide background of electronic research and development. It has definite plans for sound post-war expansion.

Applicants should be American citizens. In your letter tell us about your age and draft status; technical education and training; experience, availability and salary requirements. Interviews will be arranged in New York City, Dobbs Ferry, or some mutually convenient point. A photograph will be appreciated. Address your letter in strict confidence to

President

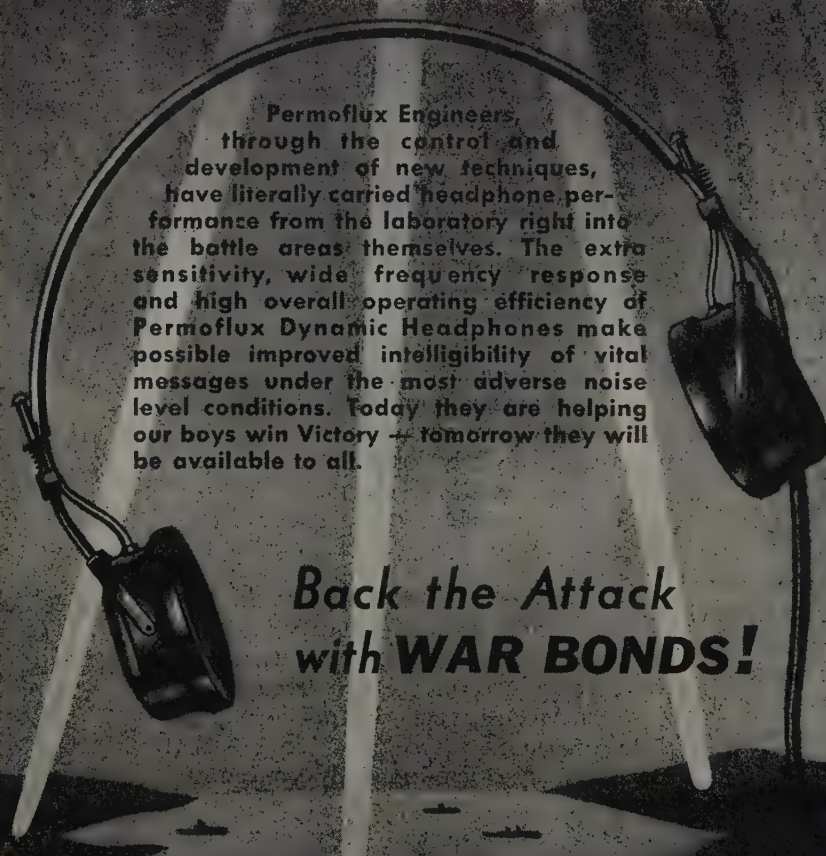
NORTH AMERICAN PHILIPS COMPANY, INC.

Dobbs Ferry, Westchester County, N. Y.

If you are now working in an essential industry at your highest skill, please do not apply.

*From the Test of War
Comes
the Better Headphone*

... Permoflux DYNAMIC



Permoflux Engineers, through the control and development of new techniques, have literally carried headphone performance from the laboratory right into the battle areas themselves. The extra sensitivity, wide frequency response and high overall operating efficiency of Permoflux Dynamic Headphones make possible improved intelligibility of vital messages under the most adverse noise level conditions. Today they are helping our boys win Victory — tomorrow they will be available to all.

**Back the Attack
with WAR BONDS!**

TRADE MARK
PERM-FLUX

CORPORATION

4916-22 W. Grand Ave., Chicago, Ill.

PIONEER MANUFACTURERS OF PERMANENT MAGNET DYNAMIC TRANSDUCERS

WANTED!

A RADIO OR ELECTRICAL ENGINEER
WITH IDEAS—AND
AN EYE TO GETTING
AHEAD AS A RESULT
OF THEM

This advertisement is addressed to an electrical engineer who is wondering what he'll be doing a year after the war has ended—where he'll be doing it—and under what conditions.

It is, however, directed only to an engineer who has the two prime requisites: Plenty of ideas and ambition to forge ahead with a small company where he will play a big part (and, if things work out as we think they will, share in the profits, too).

Briefly, a client of ours is looking to the future and has asked us to help him find such an engineer for the job involved. Although this client's business is now 100% war work, and volume amounts to several million dollars yearly, the company is not normally a large one—but it has proved its ability for over ten years to keep going profitably through good times or bad. It has an important line of well-known, finely-made Radio products to revert to in peace times but would like to have a larger, more diversified, line—and that's where the opportunity for an engineer with ideas comes into the picture. The new items he develops can either be in Radio, or far afield from it, providing only that present production machinery can be utilized in making them.

The men who run the company are young, progressive and engineering minded. They'll give the right engineer plenty of help and encouragement and he won't scare them by suggesting something radically new and different. That's what they're looking for—ideas—and, to an engineer who gives evidence of producing a reasonable share of "hits" along this line, they are prepared to make a mighty attractive offer.

The company is located in suburban Eastern Pennsylvania. It will stand rigid investigation from any angle—and it is big enough to offer ample working facilities plus many personal advantages that a much larger concern might find difficulty in duplicating.

Starting salary—well, let's not even talk about that until we've had a chance to size each other up. Suffice to say, it will be large enough to match the "size" of the man who interests our client. More important, however, is the fact that we're looking for an engineer who has an eye to something more than a salary as things progress.

If this sort of set-up sounds appealing, I suggest that you drop me a line—to be acknowledged and forwarded promptly to our client. All correspondence will be kept strictly confidential, and it goes without saying that our client's employees have been advised of this advertisement.

Harry P. Bridge, President
THE HARRY P. BRIDGE COMPANY
Advertising Counsellors
Real Estate Trust Bldg., Philadelphia 7, Pa.

BLILEY CRYSTALS

RIDE WITH THE SCR-299

Built by **hallicrafters**

ONE of the outstanding achievements in wartime radio transmitter design is the SCR-299. Serving equally well as a mobile or stationary radio station, this now famous equipment is doing a real job on our battle fronts.

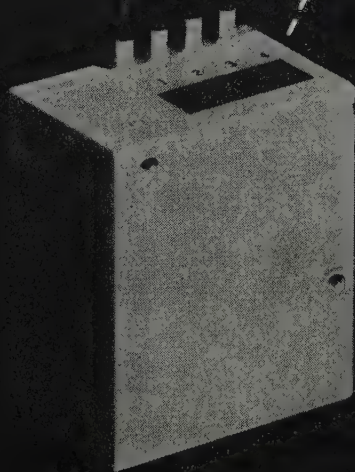
This war is run by radio. The vital importance of maintaining reliable communications necessitates the selection of quartz crystal units that are accurate and dependable. Bliley Crystals are engineered for service . . . they are used in all branches of military communications and are, of course, supplied for the SCR-299.



BACK THE ATTACK WITH WAR BONDS

BLILEY ELECTRIC CO., ERIE, PA.

**FOR
HIS EARS
ALONE**



Literally "running interference" through the ether... insuring a clear path for the one Signal which directs the safe landing of an airplane under the most adverse conditions... that is just one of the scientific miracles possible today because of

FILTERS
by

THORDARSON

THORDARSON ELECTRIC MFG. CO.
500 WEST HURON ST. CHICAGO, ILL.

INTERESTING TECHNICAL
PAPERS WILL BE SENT
FREE UPON REQUEST

Transformer Specialists Since 1895
ORIGINATORS OF TRU-FIDELITY AMPLIFIERS

POSITIONS OPEN

(Continued from page 44A)

ELECTRONIC ENGINEER

Electronic engineer with M.A., Ph.D., or the equivalent in physics, for research and design in geophysics. Experience in filter design and sound recording is desirable. Write to Independent Exploration Company, 901 Esperson Building, Houston, Texas.

ENGINEER

AAA-1 eastern manufacturer, over 75 years operation and leader in growing industry, has immediate permanent position for chemical, electrical, electronic or chemical-metallurgical engineer to organize and increase efficiency of production activities. Send full details of experience to Box 301.

RADIO OR ELECTRICAL ENGINEER

Capacitor manufacturer located in New Bedford, Mass., wants an electrical or radio engineer—man or woman—for equipment- and circuit-development work.

Permanent postwar future for right person. This firm has excellent laboratory facilities and is a leader in its field.

Applicant should be college graduate with a degree—or equivalent experience—in radio engineering or electrical engineering.

Interview in Boston, New Bedford or New York can be arranged. Traveling expenses paid to place of interview.

Write fully, giving age, education, experience, etc. Address reply to Box 302.

RADIO ENGINEERS

Well-established international corporation, 100% in war work with definite postwar possibilities, needs several radio engineers who are familiar with the construction or use of automatic-receiving equipment. Also two transmitter engineers familiar with 40 k.w. equipment.

Applicants should have college degree or approximately ten years experience in radio. Openings in Chicago and New York. Salaries from \$100.00 a week dependent upon experience and ability.

In reply please give complete details of experience, age, education, present and former employers, present earnings and your telephone number. Enclose recent photo if available. Address reply to Box 303.

ELECTROACOUSTIC ENGINEERS

Experienced in laboratory development and research activities. New positions open in the development of war-production items. Situation includes excellent opportunities for post-war employment. Salary open. Write Personnel Manager, Universal Microphone Co., Box 299, Inglewood, California.

RADIO ENGINEER

Wanted for general work covering design and installation with major communication company chiefly in New York area. Technical graduate preferred. Must have car. Position not limited to duration. Address Box 298.

RADIO ENGINEER

EDUCATION: Minimum of two years college in Electrical Engineering.

EXPERIENCE: Minimum of two years in radio test or engineering, or five years in electrical control work (power station or telephone central-office wiring, etc.).

Must be of a type qualified to interpret and clarify with inspectors and responsible executives electrical specifications, problems of manufacture, test and inspection. Address Box 290.

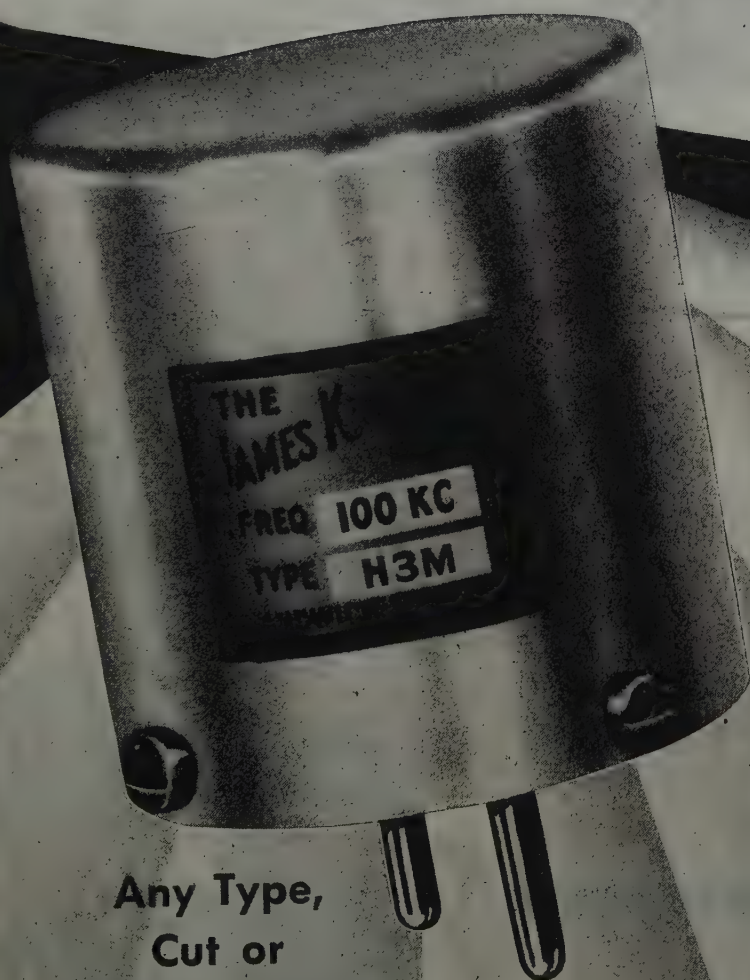
(Continued on page 50A)

Proceedings of the I.R.E., November, 1943

**JAMES
KNIGHTS**

Crystals

**MARKED FOR
DEPENDABILITY!**



**Any Type,
Cut or
Frequency**



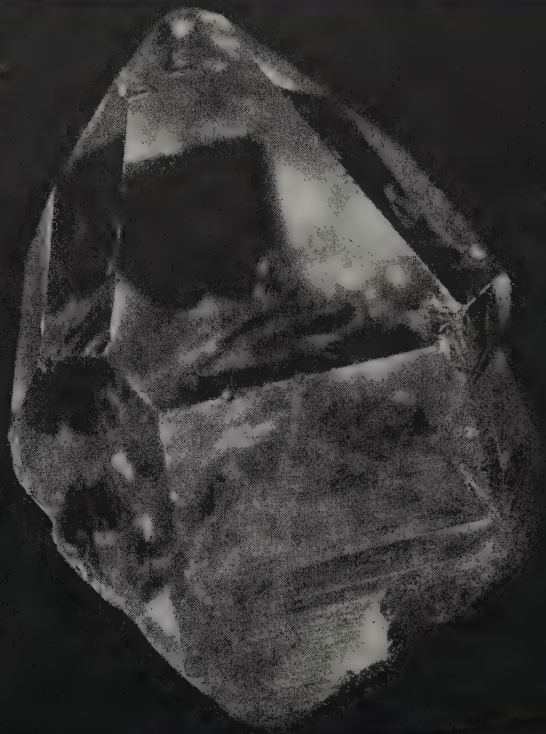
DO YOU NEED THESE TYPES!

- ★ 100 KC. coated bars—3 PPM or less per 0° Centigrade. (Other frequencies: 50 KC. to 200 KC.)
- ★ 1000 KC. precision metal tube mounted crystals
- ★ Bertrand plates
- ★ 20-23 Atomic plane standards

Precision production now available on the above special quartz products. Tell us your requirements on these or other crystal types which we may be able to supply.

**PRECISION CUTTERS OF QUARTZ
for
COMMUNICATIONS & OPTICAL USES**

The JAMES KNIGHTS Company
SANDWICH, ILLINOIS
PHONE 65



WE'RE TUNING NATURE'S EAR TO THE WAR EFFORT . . .

This piece of South American quartz crystal is remarkable for its piezo-electric properties. Ground so it responds to the proper frequency, it becomes a most important part of electronic devices used by our armed forces. . . . This grinding is a very "touchy" operation. Our special equipment and specially trained personnel are doing a fine job, we believe. . . . This is one of "Connecticut's" contributions to the war effort.

CONNECTICUT TELEPHONE & ELECTRIC DIVISION

MERIDEN,



CONNECTICUT

● Our development engineers are glad to discuss electrical and electronic product ideas which might fit in with our postwar plans. Address Mr. W. R. Curtiss at the above address.



(Continued from page 43A)

INSTRUCTORS IN ADVANCED ARMY-NAVY PROGRAM

Prominent Eastern technical institute needs additional instructors in officer training program in modern electronics and radio applications. An excellent opportunity to acquire advanced knowledge and to render important service in war effort. Men having various degrees of qualifications are needed, from recent graduates in Electrical Engineering or Physics to those with long experience in radio engineering or teaching. Salary according to qualifications and experience. Applicants must be U. S. citizens of unimpeachable reputation. Any inquiries will be treated as highly confidential. Please send personnel data and photograph to Box 292.

RADIO AND ELECTRONIC ENGINEERS

First, we are seeking the services of one or two trained engineers who have had ample experience in electronic engineering. The men selected will not only be concerned with present war production, but should eventually develop key positions in postwar operation.

Second, we are also looking for a few young engineers who have had good schooling and background to be trained for specialized work with us.

This is an excellent opportunity for men who qualify to connect with a progressive, highly regarded manufacturer of transmitting tubes. Many special benefits will be enjoyed in your association with this company.

Write at once giving complete details of past experience. Interviews will be promptly arranged. Persons in war work or essential activity not considered without statement of availability. Chief Engineer, United Electronics Company, 42 Spring Street, Newark, New Jersey.

PHYSICIST OR ELECTRICAL ENGINEER

Leading manufacturer of industrial radio-frequency equipment desires the services of a physicist or electrical engineer to direct developmental and applications laboratory. This field is expanding rapidly and offers excellent opportunities for advancement. Position of a permanent nature. Present activities devoted entirely to the war effort. Address replies to Box 306.

SOUND AND PROJECTION ENGINEERS

Openings exist for sound and projection engineers. Several years experience in the installation and maintenance of 35 mm motion-picture equipment of all types required. Must be draft exempt or over draft age and free to travel anywhere in the United States. Basic starting salary \$3200. U. S. Army Motion Picture Service, Engineering and Maintenance Division, 3327-A Locust Street, St. Louis, Missouri.

ELECTRICAL ENGINEER

An opportunity is offered to do interesting, varied and broadening development and laboratory work on highest quality electromagnetic devices used in fighting equipment. Salary will be good and commensurate with experience. A good post-war position is indicated by our being a moderate-sized, live-wire, long-established company with a non-inflated engineering staff. A knowledge of communication circuits is desirable but not essential. An engineering or science degree and a good knowledge of fundamentals are required. Write to G-M Laboratories, 4326 N. Knox Avenue, Chicago, Illinois.

RADIO ENGINEERS

Permanent radio-engineering position in Southern California for men with creative and design aptitude, especially with UHF circuits. Starting salary and advancement depends upon the engineer's experience and ability.

Applications are solicited from persons that are not using their highest skills in war work.

Write complete qualifying educational training and experience to Chief Radio Engineer, Bendix Aviation, Ltd., in care of The Shaw Company, 816 W. 5th Street, Los Angeles 13, California.

The foregoing positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No.

B-Z-Z-Z-Z



BZZZ . . . BZZZ . . . ugly rumors work their way from mouth-to-mouth. **YOU HEAR** that our best grades of food are sent overseas and we are given the leavings. **YOU HEAR** that the need for purchasing war bonds is just so much talk. **YOU HEAR** that inferior implements are given our soldiers.

THE truth of the matter is that these rumors are bare-faced lies . . . spread around to cause fear and confusion. America is still the best-fed nation in the world . . . it's more important than ever that you keep buying war bonds . . . and, as for inferior war materials, you know, and we know, that American equipment is the best. Speaking solely for ourselves, Kenyon Transformers have been put to any

number of gruelling tests . . . and they've emerged with flying colors.

Yes, you hear all sorts of rumors these days. They're inspired to set Americans against each other . . . management against labor, color against color, race against race. Do your part to stamp out this evil practice. **Investigate before you believe!** Remember, united we stand, divided we fall.

BUY WAR BONDS—10% is only a start. Every dollar invested in war bonds is a vote for victory. Keep on backing the attack.



THE MARK OF

EXCELLENCE

KENYON TRANSFORMER CO., Inc. 840 BARRY STREET
NEW YORK, U. S. A.

VICTORY...in the Making

Here, at Doolittle, we are coordinating every effort and skill to help provide the communications equipment so essential for Victory. This will mean better peace-time communications after our battles are won.



To Assure Victory
Buy More U. S. War
Bonds and Stamps

Doolittle
RADIO, INC.

Builders of Precision Radio Communications Equipment
7421 S. Loomis Blvd., Chicago, U. S. A.

★ INTERMEDIATE AMPLIFIER STRIP



Available with
Various Electrical Characteristics

I-F AMPLIFICATION - AUDIO AMPLIFICATION

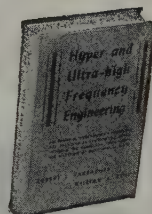
HARVEY Radio Laboratories, Inc.
445 CONCORD AVENUE • CAMBRIDGE • MASS.

ENGINEERS!

New Material on a New
Branch of
**COMMUNICATION
ENGINEERING**

**HYPER & ULTRA HIGH
FREQUENCY
ENGINEERING**

By Robert I. Sarbacher
and
William A. Edson



If you are an engineer in any branch of communications work—in a radio plant producing UHF war apparatus, in a radio or electronics research laboratory, **HYPER AND ULTRA-HIGH FREQUENCY ENGINEERING** will give you the basic theory and its present-day application to radio, electronics, ultra-high frequencies, and microwaves.

Specifically, the wide range of topics in "Sarbacher and Edson" includes an introduction to mathematical and physical concepts necessary for a comprehensive understanding of microwave and ultra-short wave transmission. Elementary electromagnetic field theory, both static and dynamic, is reviewed. The derivation and application of field equations is fully explained.

Performance of transmission lines of both conventional and hollow form is discussed in terms of circuit and field theory. Operation of the more important forms of hyper-frequency generators is covered. In fact, all phases of hyper-frequency engineering—including generation, transmission and radiation of these quasi-optical waves—are discussed, as critics phrase it, for the first time in adequate detail.

"Sarbacher and Edson" brings you those unchanging fundamentals essential to an understanding of new communications developments together with the latest UHF engineering data permitted to be released at this time. Send for your copy today.

644 pages 5 1/2 x 8 1/2 \$5.50

---ON APPROVAL COUPON---

JOHN WILEY & SONS, INC.
440 Fourth Avenue, New York 16, N.Y.
Please send me a copy of Sarbacher-Edson's **HYPER AND ULTRA-HIGH FREQUENCY ENGINEERING** on ten days' approval. At the end of that time, if I decide to keep the book, I will remit \$5.50 plus postage; otherwise I will return the book postpaid.

Name
Address
City and State
Employed by

IRE-11-43

Behind all mechanical precision

DISCIPLINED **Electrical Power**

WHEN EACH SMALL PART, as it comes from the machine—each finished article, as it comes from the assembly line—*varies not at all* from the others, the problems of **QUALITY** production have been solved, and **QUANTITY** production presents small difficulty.

Modern electrically operated manufacturing equipment is expertly designed to produce with *absolute exactness*. That's the miracle behind today's output. *But*, the mechanical perfection of each individual unit must be matched by an un-failing, unvarying power supply. Every unit, however small, must be responsible for its own security. That is why SOLA Constant Voltage Transformers are widely used to provide protection against damaging voltage variation.

Where this control is lacking, electrically operated or controlled equipment is highly vulnerable to voltage fluctuations. Devices designed to operate at rated voltages *react differently* to

drops or increases in voltage. Then uniform accuracy and synchronization of the production line no longer exists. Precision work becomes impossible. Rejects increase in number.

SOLA "CVs" protect equipment and instruments, absorbing voltage sags and surges up to 30% and deliver an unchanging, specific voltage regardless of input variations from over-loaded supply lines.

Automatic and instantaneous in action, SOLA "CVs" allow no jolts or sags to slip through. They are made with the same modern exactitude as the most intricate equipment. Immediately available in standard units, capacities from 10 VA to 15 KVA, SOLA Constant Voltage Transformers can also be built to your specification.

Note to Industrial Executives: *Where there is a problem involving voltage control, no matter what its nature, SOLA "CV" Transformers can help solve it. Ask for bulletin KCV-74.*

SOLA

Constant Voltage Transformers

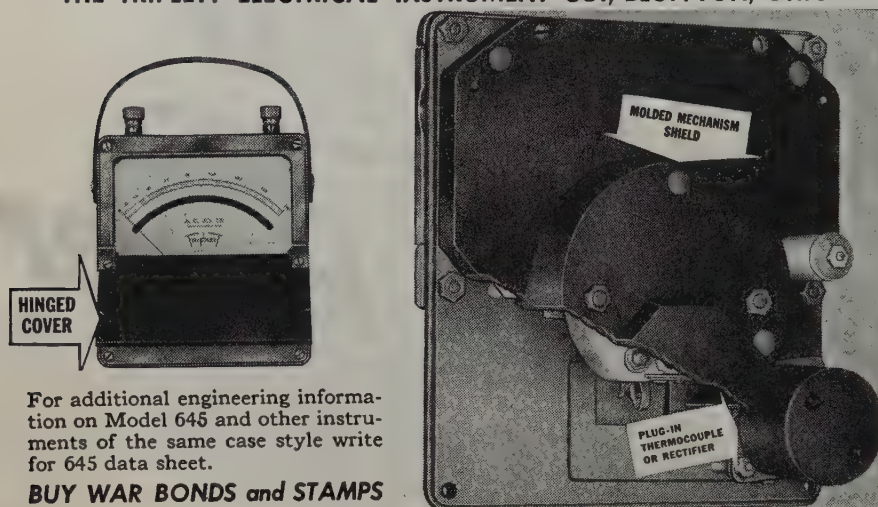
Transformers for: Constant Voltage • Cold Cathode Lighting • Mercury Lamps • Series Lighting • Fluorescent Lighting • X-Ray Equipment • Luminous Tube Signs • Oil Burner Ignition • Radio • Power • Controls • Signal Systems • Door Bells and Chimes • etc. **SOLA ELECTRIC CO., 2525 Clybourn Ave., Chicago, Ill.**

TRIPLET Practi-Quality

PRECISION—DURABILITY—FAIR PRICES

TRIPLET MODEL 645 PORTABLE. Hinged cover protection. Opens flush. Smooth case open or closed. Molded shield protects movement, excludes dust, permits plug-in thermocouple or rectifier replacements without exposing sensitive mechanism. Pre-calibration of thermocouples or rectifiers made possible by interchangeable plug-in units. No re-calibration required. In burn-out of thermocouple or rectifier new replacement can be affected "on the job".

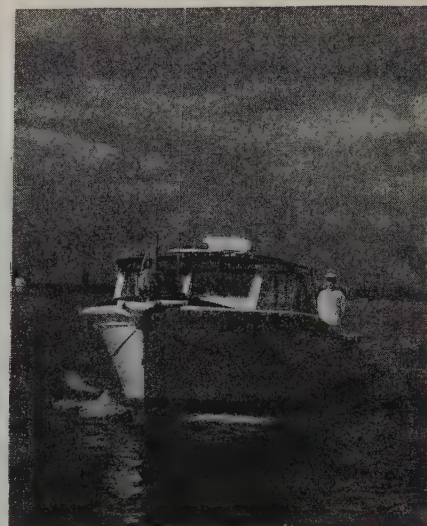
THE TRIPLET ELECTRICAL INSTRUMENT CO., BLUFFTON, OHIO



For additional engineering information on Model 645 and other instruments of the same case style write for 645 data sheet.

BUY WAR BONDS and STAMPS

PREMAX



—Pan-American Airways Photo

RADIO ANTENNAS

**Are Serving
On Land and Sea**

Premax Antennas in standard and special designs are proving themselves every day at airports, in military and commercial installations on land and sea. For the important task of maintaining communications under most adverse conditions, Premax Antennas are outstanding.

Emergency repair crews in public utilities are also finding these Antennas equally valuable in their regular work.

Undoubtedly one of Premax's many standard or special designs will admirably fill your requirements for dependable antennas and mountings.

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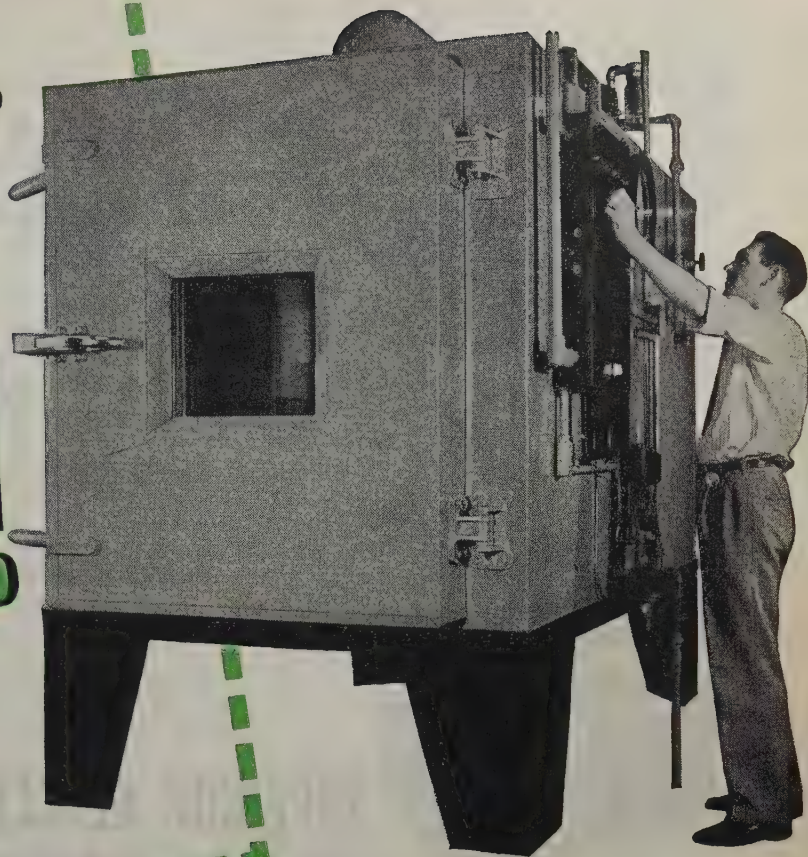
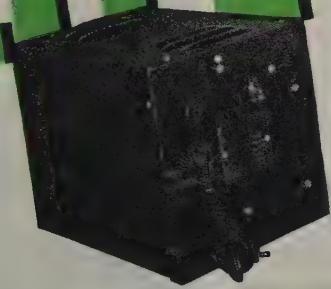
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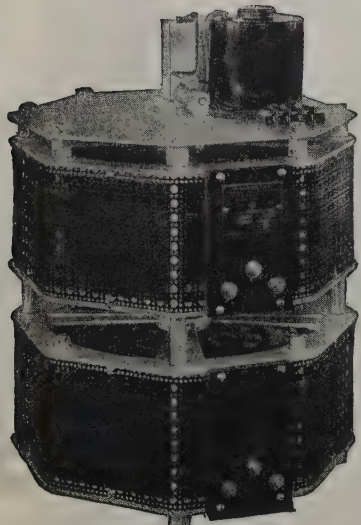
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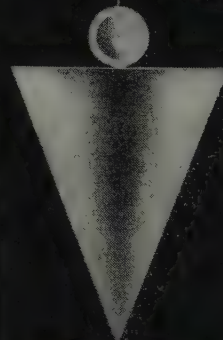
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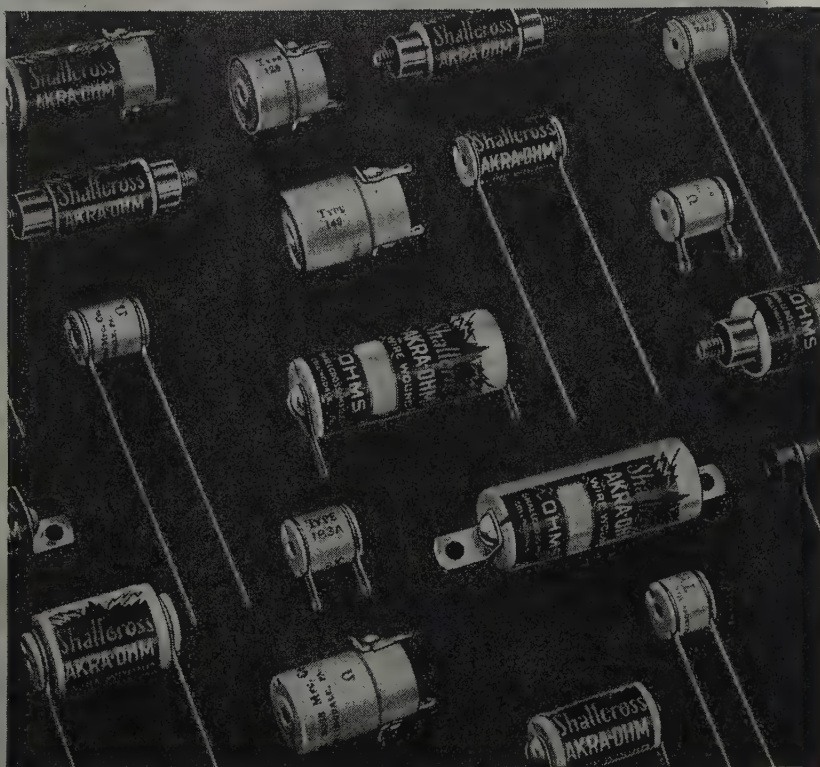
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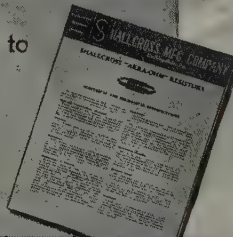


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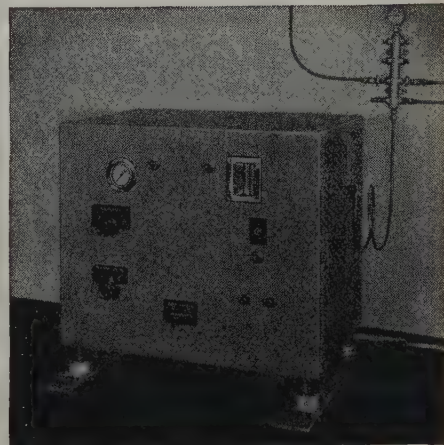


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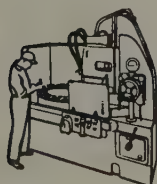
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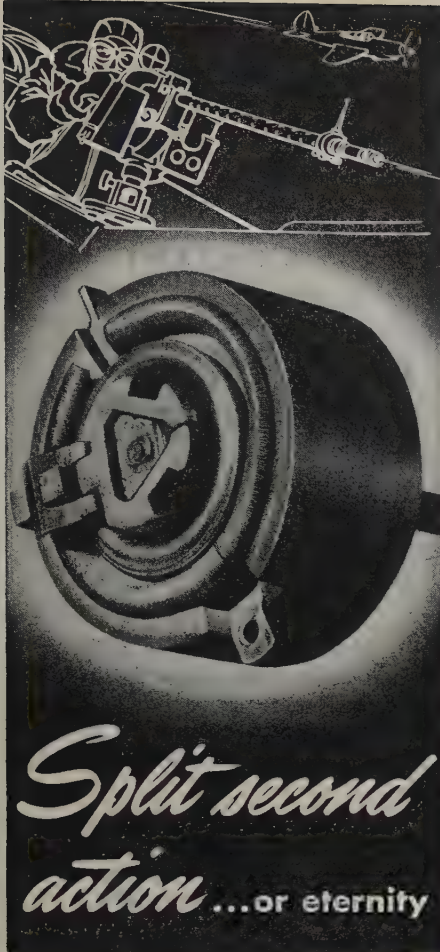
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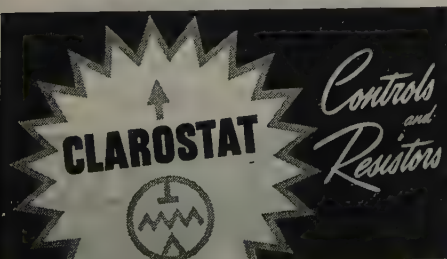
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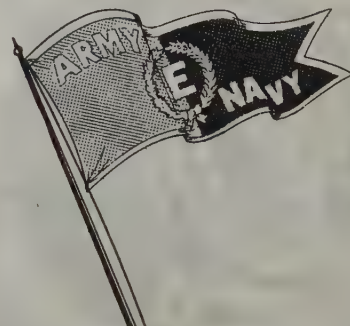


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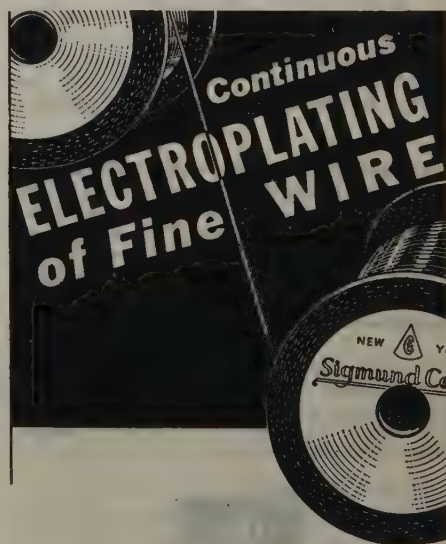
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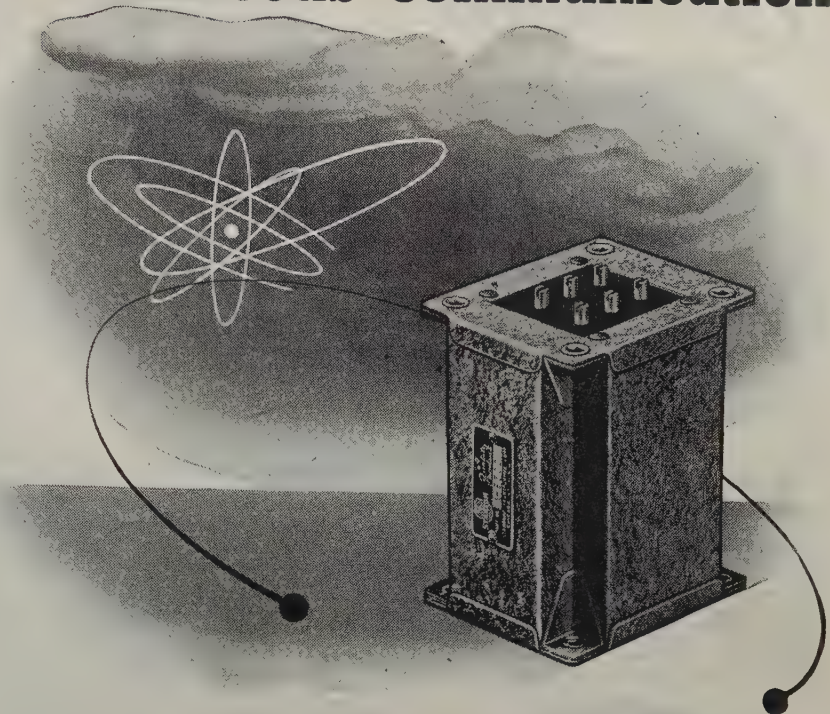
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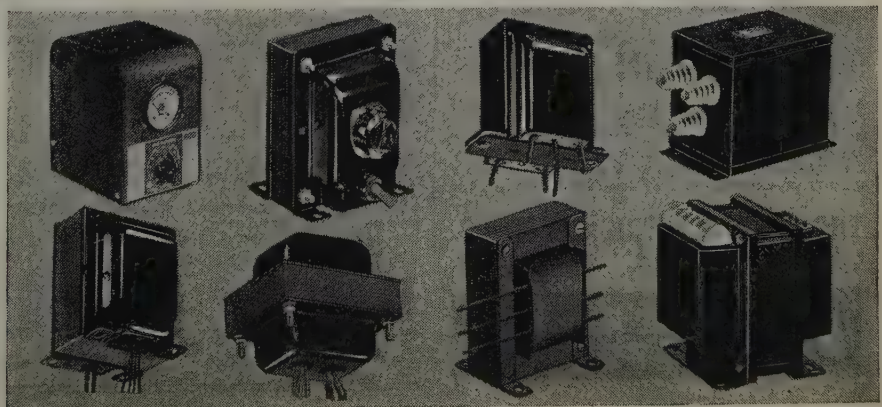
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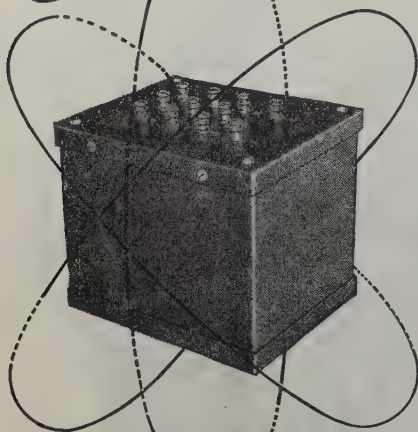
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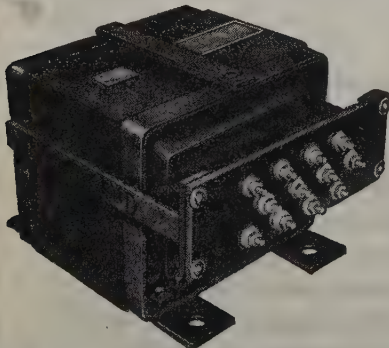


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INDEX

Section Meetings	34A
Membership	34A
Army-Navy "E" Honor Roll	40A
Positions Open	44A

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Acme Electric & Mfg. Company	66A
Aerovox Corporation	6A
Aircraft Accessories Corp.	23A
Alliance Mfg. Company	36A
American Lava Corporation	27A
American Telephone & Telegraph Co.	8A
American Transformer Company	5A
Amperex Electronic Products, Inc.	Cover II
Arnold Engineering Company	62A

Bendix Aviation, Ltd.	Facing 17A
Bendix Radio Division	Facing 16A
Bliley Electric Company	47A
Harry P. Bridge Co.	46A

Centralab	41A
Chicago Telephone Supply Co.	2A, 3A
Chicago Transformer Corp.	38A
Clarostat Mfg. Company, Inc.	63A
Sigmund Cohn & Co.	64A
Communication Products Co.	60A
Connecticut Telephone & Electric Div.	50A
Cornell-Dubilier Electric Corp.	Cover III

Daven Company	13A
DeJur-Amsco Corp.	24A
Tobe Deutschmann Corp.	67A
Doolittle Radio, Inc.	52A
Wilbur B. Driver Co.	21A
Allen B. DuMont Laboratories, Inc.	12A
DX Crystal Company	62A

Eitel-McCullough, Inc.	68A
Electronic Corp. of America	14A
Electronic Laboratories, Inc.	57A
Electro-Voice Mfg. Co., Inc.	16A
Espey Manufacturing Co.	64A

Federal Telephone & Radio Corp.	61A
Galvin Manufacturing Corp.	31A
General Electric Company	56A
General Electronics Industries, Div. of Auto-Ordnance Corp.	65A
General Instrument Corp.	30A
General Radio Company	Cover IV

Hallcrafters Company	22A
Harvey Radio Laboratories, Inc.	52A
Heintz & Kaufman, Ltd.	55A
Hewlett-Packard Company	39A
Hytron Corporation	26A

Industrial Condenser Corp.	40A
International Resistance Co.	33A
International Tel. & Tel. Corp.	61A

Jackson Electrical Instrument Co.	56A
Kenyon Transformer Co., Inc.	51A
James Knights Company	49A

Lafayette Radio Corp.	63A
Measurements Corporation	58A
Merit Coil & Transformer Corp.	54A

National Company, Inc.	25A
National Union Radio Corp.	37A
New York Transformer Co.	62A
North American Philips Co., Inc.	45A

Ohmite Mfg. Company	35A
Operadio Manufacturing Co.	66A

Permoflux Corp.	46A
Pioneer Gen-E-Motor	42A
Premax Products	54A
Pyroferic Company	58A

Radio Corp. of America, Victor Div.	9A, 29A, 32A
Rauland Corporation	20A
Raytheon Manufacturing Co.	15A
Remler Company, Ltd.	44A
Rola Company	10A

Shallcross Mfg. Company	60A
Shure Brothers	43A
Sola Electric Company	53A
Sprague Specialties Co.	11A
Standard Transformer Corp.	65A
Stupakoff Ceramic & Mfg. Company	4A
Sun Radio Company	66A
Superior Electric Company	58A

Thordarson Elec. Mfg. Co.	48A
Triplett Electrical Instrument Co.	54A

United Electronics Company	59A
United Transformer Company	18A
Universal Microphone Co., Ltd.	64A
Utah Radio Products Co.	17A

Wm. T. Wallace Mfg. Co.	34A
Westinghouse Elec. & Mfg. Co.	7A
Wilcox Electric Co.	19A
John Wiley & Sons, Inc.	52A

Zenith Radio Corporation	28A
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Lists countless thousands of standard and "hard-to-get" radio and electronic items—most of which we carry in stock! Send for it today if you are actively engaged in purchasing, specifying or expediting for the war effort. Address Box RN.

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Buying
Guide

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RADIO CO.
212 FULTON ST.
NEW YORK, N. Y.



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"Electronics"

...but the first "talkies" were just as unbelievable as the electronic miracles that are revolutionizing war today . . . and may revolutionize your business tomorrow! When you need help on electronic applications to your product or process, remember Operadio—first to offer an alternating current operated theatre amplifier for the "talkies"—a pioneer in electronic development.

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Electronic Specialists

OPERADIO MANUFACTURING COMPANY, ST. CHARLES, ILL.

FOR A LONG, LONG TIME



One reason why Tobe Capacitors have forged to the front is their consistently long life. But there's another reason — the successful pioneering work of Tobe engineers.

Take as an example the CA-355, shown below in streamlined, hermetically sealed drawn container. It is being used in large quantities by the U. S. Army Signal Corps in front line telephones.

Tobe is the only manufacturer furnishing this capacitor in a drawn container.

The CA-355 is just one instance of Tobe engineering ingenuity in developing and perfecting new devices. However tough your own condenser problems we invite the opportunity for our engineers to help you solve them. Please get in touch with us.

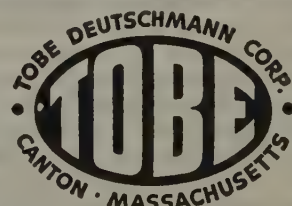


LONG-LIFE ASSURED
For This Unique Capacitor

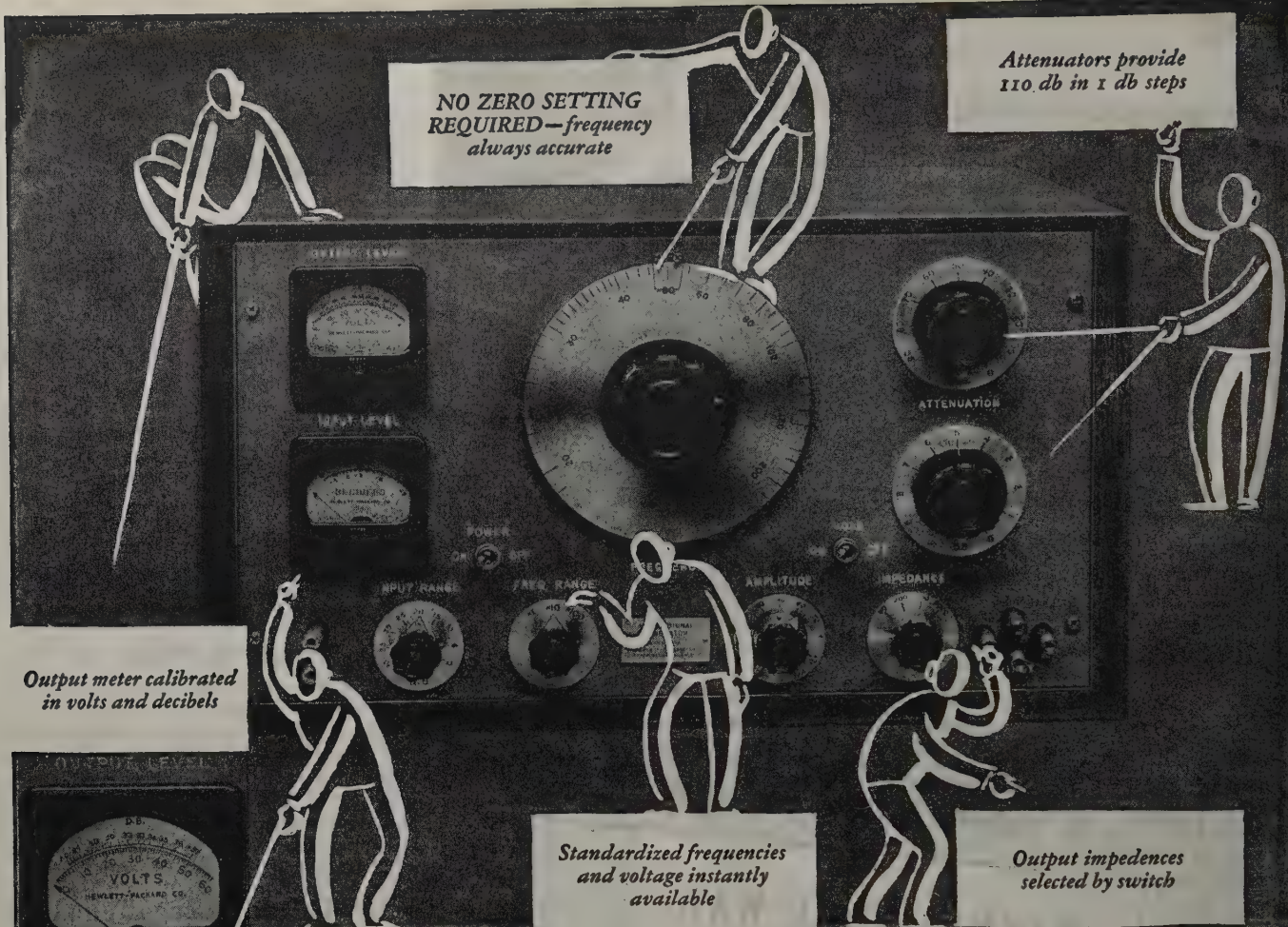
SPECIFICATIONS—CA-355

Wax impregnated, wax filled capacitor
Capacity Rating:.....2.0—0.5—0.3 mfd.
Voltage Rating:.....200 D C
Power Factor:..@ 1000 cycles .01 maximum
Resistance:.....2000 megohms per microfarad
Dimension: 1" depth—2½" length—2½" height

Meets requirements of U. S. Army Signal Corps



A small part in victory today—A BIG PART IN INDUSTRY TOMORROW



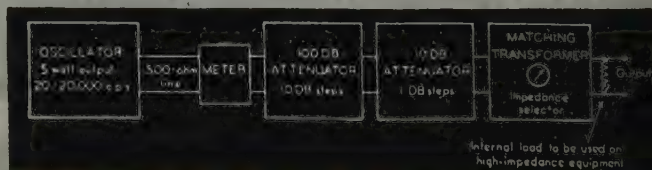
Six reasons why this AUDIO SIGNAL GENERATOR saves your time and insures better accuracy

This all-in-one combination of instruments insures the utmost of speed without sacrifice of accuracy in making certain laboratory and production measurements. The model 205AG consists of an *-hp-* Resistance Tuned Audio Oscillator, an output meter, attenuator and an impedance matching system. In addition a separate input meter is provided. Thus no auxiliary equipment is required in making gain measurements. It is ideal for general laboratory applications because it supplies a known voltage and a known frequency at the commonly used impedance levels.

Of outstanding importance is the fact that the Resistance Tuned Oscillator requires no zero setting. The frequency drift is negligible even during the first few

minutes of operation. The constant output of this oscillator makes it ideal for checking frequency response of apparatus. Waveform distortion is very small, hence this instrument provides an excellent source of voltage for distortion measurements.

Below is a block diagram showing the arrangement of the components in the Model 205AG Audio Signal Generator. Get full information about this and other *-hp-* laboratory instruments. Ask for your copy of the 26-page fully illustrated catalog which gives valuable data on making tests and measurements as well as details of the *-hp-* line of instruments.



HEWLETT-PACKARD COMPANY


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he can do your work . . .

. . . *if* you are not really concerned about what happens to your designs after they leave the drafting board. And if the choice of electronic tubes and other components is left to chance, the performance of the finished product can scarcely measure up to the engineers' conception of it. Imagination is the well-spring of true progress in the field of electronics . . . but the performance of the most finely conceived design is no better than the tubes incorporated in it.

The name Raytheon is synonymous with quality and dependability wherever tubes are in use. When production can again be directed to civilian use Raytheon tubes will be built better than ever before . . . the engineering of Raytheon tubes will afford hitherto undreamed of new horizons for amateur, commercial and industrial radio.



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Each Division of Raytheon
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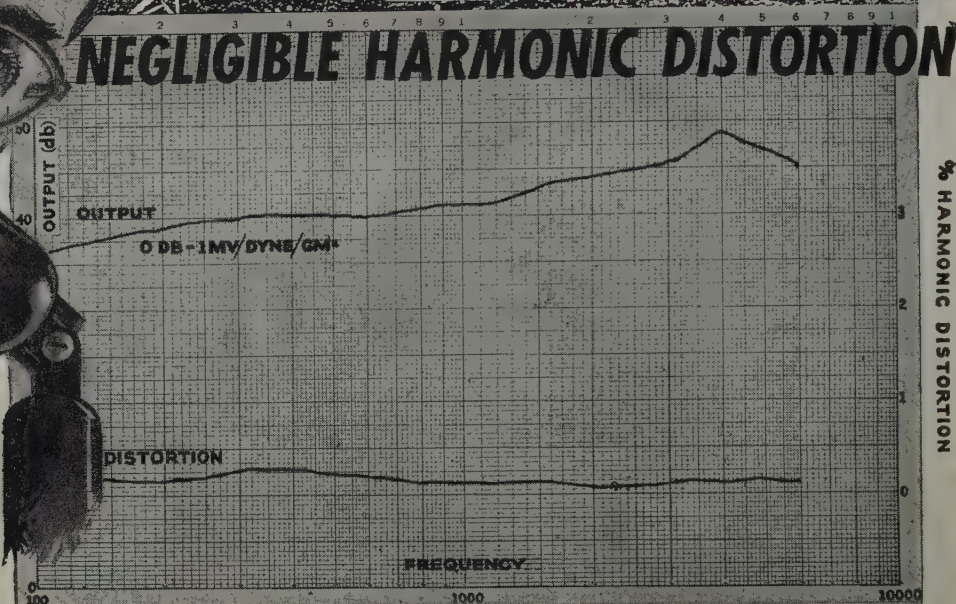
RAYTHEON

RAYTHEON MANUFACTURING COMPANY
Waltham and Newton, Massachusetts

DEVOTED TO RESEARCH AND THE MANUFACTURE OF TUBES AND EQUIPMENT FOR THE NEW ERA OF ELECTRONICS



NEGLIGIBLE HARMONIC DISTORTION

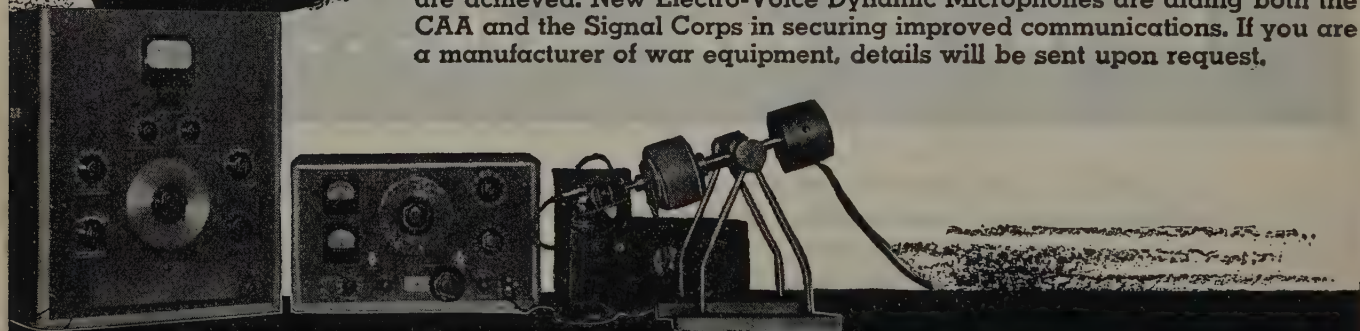


A Statement of Fact —Not a Boast

Every microphone manufactured by Electro-Voice has been designed and developed by our engineers—many in collaboration with the U. S. Army Signal Corps.

Harmonic distortion is the addition of spurious frequencies to the fundamental in definite harmonic relationship. Though the frequency curve may be excellent, harmonic distortion turns up as raspy reproductions, with an unnatural twang, in microphones, amplifiers and speakers. Five percent is considered a satisfactory upper limit for good reproduction, and as much as fifteen percent is allowable for speech communication.

Now come new Electro-Voice Dynamic Microphones with radical innovations in diaphragm fabrication, reducing harmonic distortion to a lower degree than hitherto possible. Cleaner, crisper, more highly intelligible reproductions are achieved. New Electro-Voice Dynamic Microphones are aiding both the CAA and the Signal Corps in securing improved communications. If you are a manufacturer of war equipment, details will be sent upon request.



The Harmonic Wave Analyzer measures the presence of spurious frequencies introduced by microphone distortion. To the ear, such frequencies give the feeling of ragged and false speech quality that may be unintelligible under the stress and strain of battle.

Electro-Voice engineers have found a way to eliminate harmonic distortion in microphone design, as proved by the Wave Analyzer; and the completely natural reproduction from the new Electro-Voice microphones.



Electro-Voice MICROPHONES

ELECTRO-VOICE MANUFACTURING CO., INC. • 1239 SOUTH BEND AVENUE • SOUTH BEND, INDIANA
Export Division: 13 East 40th Street, New York 16, N. Y. — U. S. A. Cables: ARLAB

More Bendix-designed UHF radio communication equipment and automatic radio compasses than all other makes combined...



NOW USED OVER EUROPE BY U. S. ARMY AIR FORCES

American war birds are darting at Fortress Europa... and in their wake hover mighty fleets for airborne invasion. Our fighters, bombers and transports will darken Axis skies.

In the job of guiding them to secret destinations, and directing and coordinating their swift, complex manoeuvres, Bendix Radio* Equipment will fill a vital role.

For in the European theatre, the U. S. Army Air Forces use more Bendix-designed UHF Communication Equipment and Automatic Radio Compasses than all other makes combined. The reason: Designing and producing such equipment for air-

craft has been the highly specialized business of Bendix Radio from its very inception... long before the war.

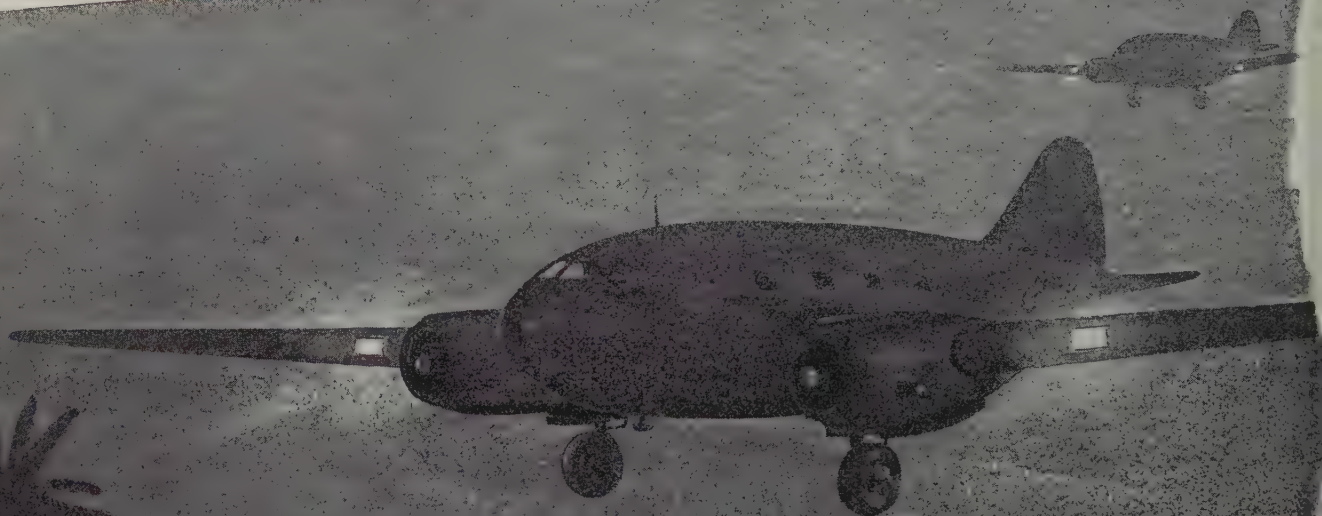
Just as Bendix Radio has set the pace in Aircraft Electronic Equipment for wartime application, so it will lead in developing new electronic marvels for peacetime flight, thus helping make *The Vehicles of Victory... the Transports of Tomorrow.*



* TRADE MARK OF BENDIX AVIATION CORPORATION

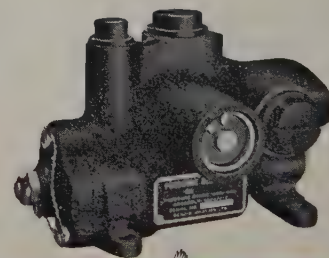
BENDIX RADIO

**BRINGS
'EM IN!**

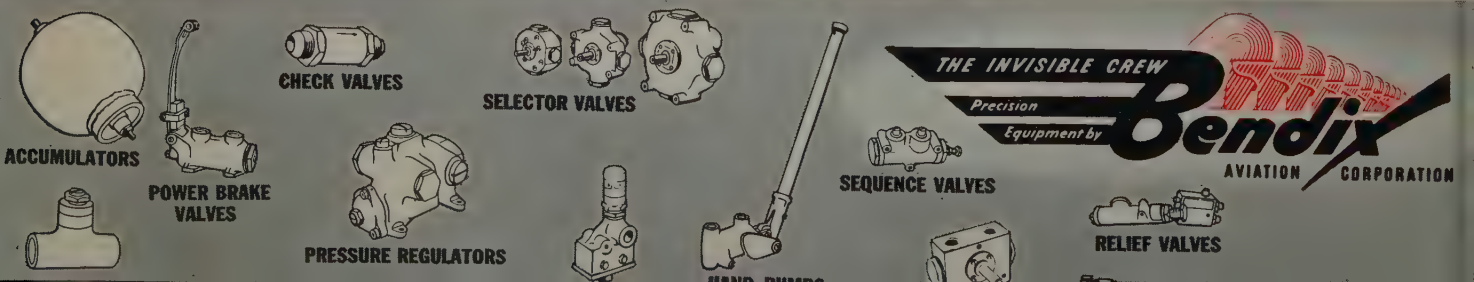


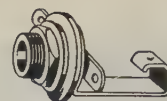
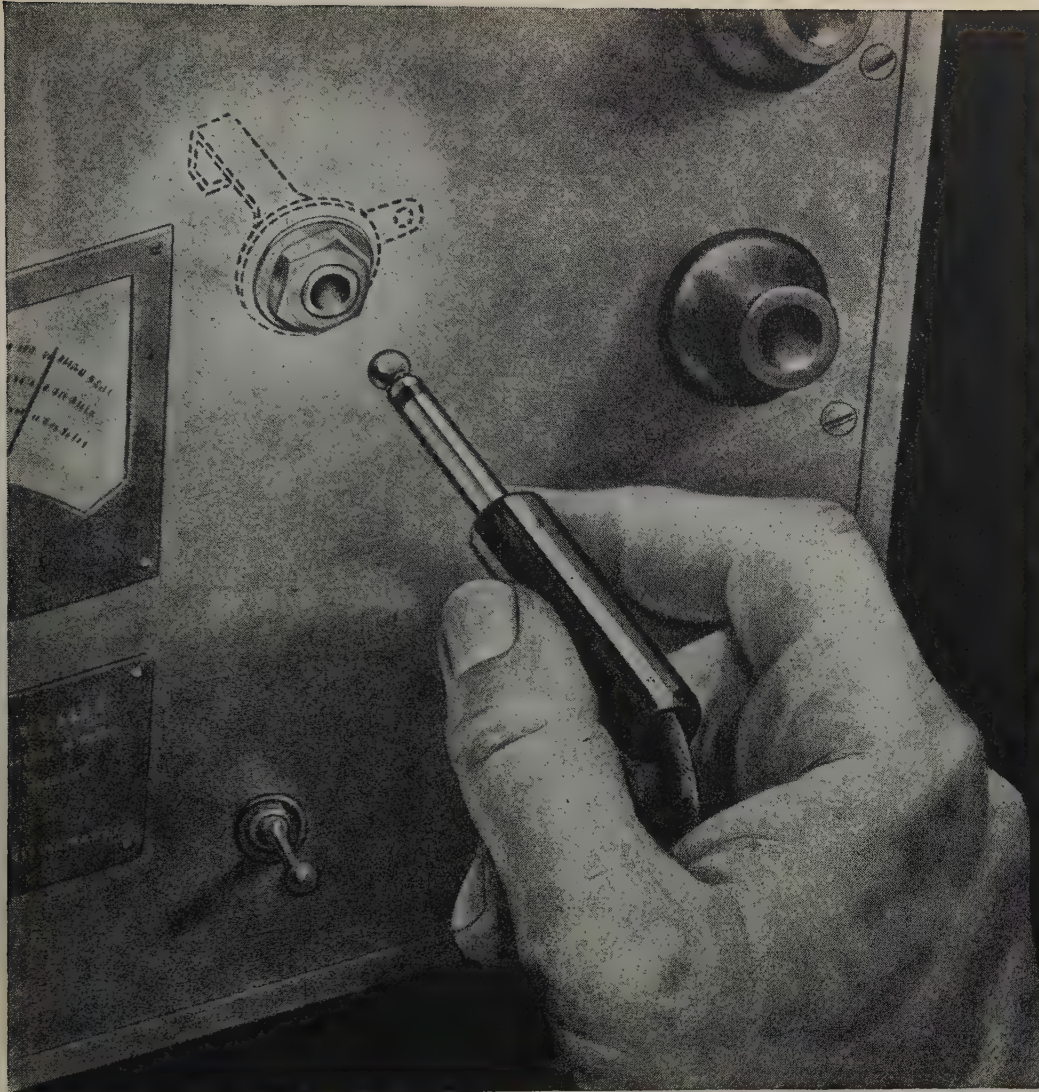
Shuttle service to the world! Back and forth to the outposts of this global war these Curtiss Commandos are bringing 'em in—box car loads of vital materiel and supplies...and the wounded.

We are proud that The Invisible Crew flies with the C-46s as it does on virtually every other U. S. plane in war service today. Bendix Aviation, Ltd., North Hollywood, California.

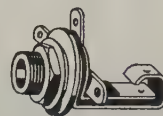


THE BENDIX PRESSURE REGULATOR is one of the many Bendix Aviation, Ltd., hydraulic controls that is being manufactured to the new AN standards. It has been designed to meet all requirements of specification AN-R-6 and drawing AN 6206. Plastic poppets are used exclusively; they seal without pre-seating operations and permit field interchangeability of parts. The regulator is quiet in operation, free of hydraulic shocks, and the change in operating differential is negligible from normal temperatures down to -65°F

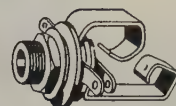




OPEN CIRCUIT JACK



CLOSED CIRCUIT JACK



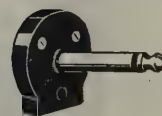
MICROPHONE JACK



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ONE-WAY PLUG



FLAT PLUG

utah CAN HELP YOU MAKE THE RIGHT "CONTACTS"...

THE right "contacts" are always important. In electrical and electronic applications a poor contact can mean costly losses. By using Utah Jacks and Plugs you can be sure that your equipment will not fail from the want of proper contact. They have been tested in the laboratory and in actual use thousands of times, answering every test successfully—under all types of conditions.

UTAH PHONE JACKS are everything that selected materials and human ingenuity can make them. They are available in Imp, Short and Long frame types to fit the standard phone plugs. Special Jacks are also made to meet Navy and Signal Corps Specifications.

UTAH PHONE PLUGS can be supplied in two or three conductor types—for practically every type of application.

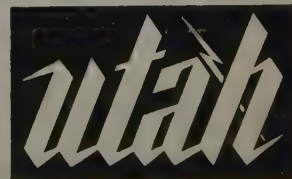
Compact, sturdy and dependable—they're all a plug should be. Utah standard plugs are being used on many products destined for use by the Armed Forces. In addition, special plugs are being manufactured.

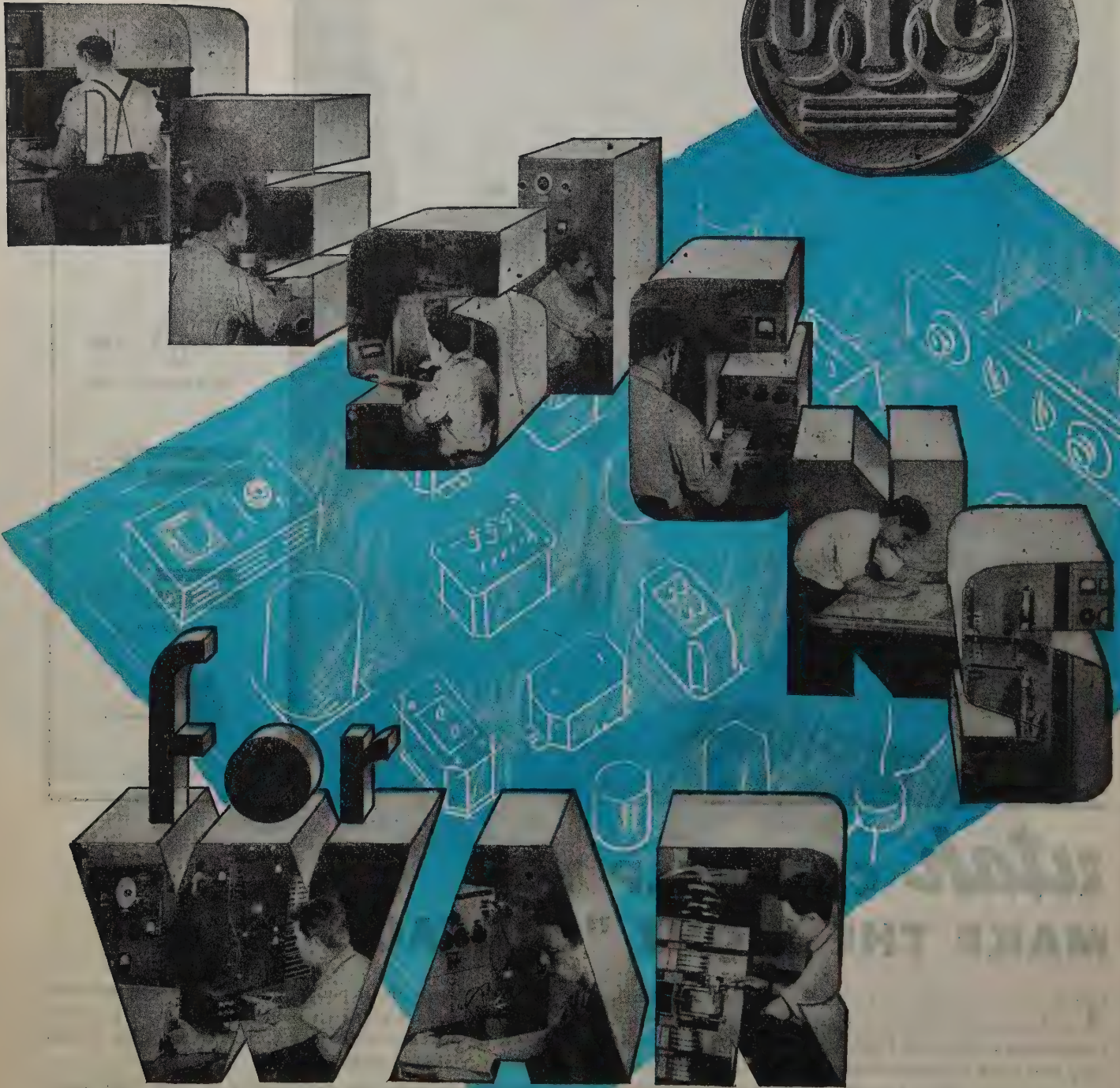
Investigate today the possibilities of using Utah Jacks and Plugs in your electrical applications. You'll be assured of absolute dependability—and you'll be cashing in on Utah's extensive electrical and electronic experience. Write today for full information on Utah's Jacks and Plugs—it may save you considerable time and money.

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WIREWOUND CONTROLS, PLUGS, JACKS, SWITCHES, ELECTRIC MOTORS**

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The bulk of UTC production today is on special units designed to specific customers' requirements. Over 5,000 new war designs were developed this past year. These designs ran from open type units to hermetically sealed items capable of many cycles of high and low temperature and extreme submersion tests. They included units from $\frac{1}{3}$ ounce in weight to 10,000 lbs. in weight and from infinitesimal voltages to 250,000 volts. It is impossible to describe all these thousands of special designs as they become available. Our staff of application engineers will be more than pleased to discuss your problem as related to special components.

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WILCOX EQUIPMENT

used by major Airlines throughout the United States

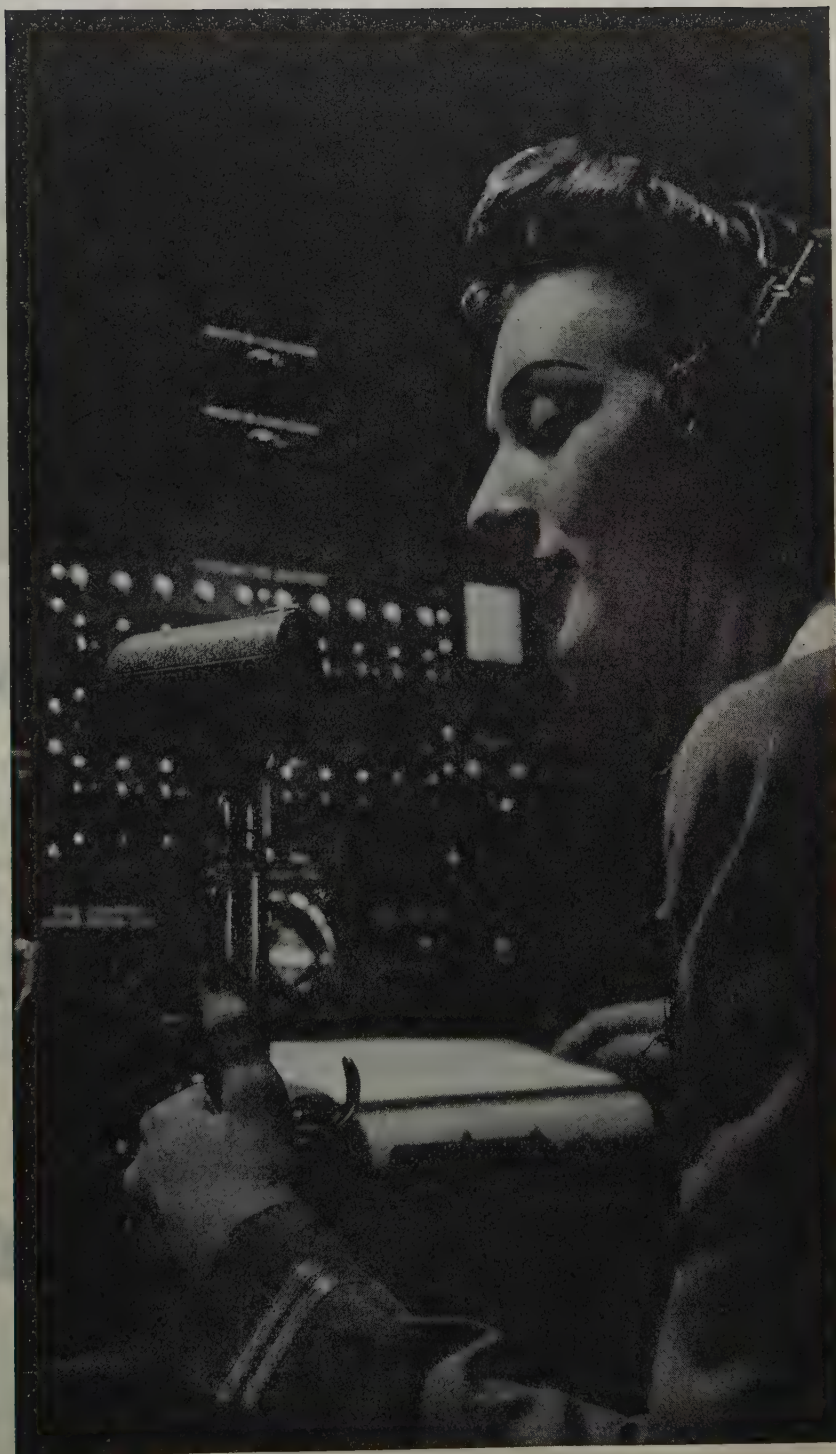
Proof of quality and dependability is in performance. Wilcox radio equipment is installed on major Commercial airlines throughout America, and in addition it is being used throughout the entire world in connection with military operations. For airline radio communications, depend on Wilcox!



**WILCOX ELECTRIC
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*Quality Manufacturing
of Radio Equipment*

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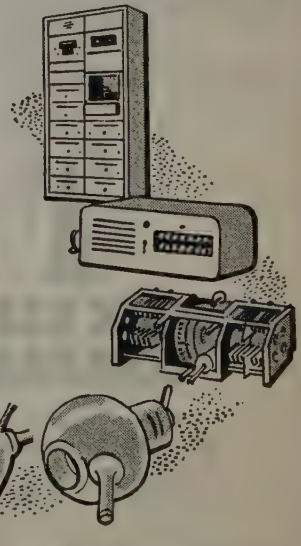




Doorway to Electronic Vision

Control of the forces of electronics begins with vision . . . especially by experienced engineering minds accustomed to achievement. RAULAND engineers and scientists have earned recognition in the field of electronic achievement with such notable examples as (1) *High Powered Cathode Ray Tubes* for large screen (15 foot x 20 foot) television projection of fine line definition. (2) *Frequency Standards* having a control accuracy of 1/100th of 1% and maintaining this almost unbelievable control throughout the entire temperature range of minus 30°C to plus 50°C. (3) *Communications*, as exemplified by precision-built transmitting type tuning condensers, two-way radio and intercommunicating and sound control units for industry. All of the fruits of RAULAND *Electroneering** are at work for our war effort today as they will serve industry in the new days to come.

* The Rauland word for all of the carefully thought out steps in electronics from vision to completion.



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Rauland

... COMMUNICATIONS

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Buy War Bonds and Stamps! Rauland employees are still investing 10% of their salaries in War Bonds

SENSITIVE...



...as a Weathercock to the breeze!

The demands of war in an industrial as well as a military sense, are ever changing. We must be sensitive to these changes — always ready to meet them, regardless of the cost in disappointment, upset schedules, temporary confusion, more work where it seemed that the most possible was already being done. We constantly endeavor to make this the keynote of our operations, realizing its necessity in hastening ultimate victory!



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FOR RADIO MEN IN THE SERVICE! "WRITE A LETTER"

As you know, the Hallicrafters make a wide range of Radio Communications equipment, including the SCR-299 Mobile Communications unit. We are proud of our handiwork, proud of the job you men have been doing

with them on every battlefield.

RULES FOR THE CONTEST

We want letters telling of actual experiences with this equipment. We will give \$100.00 for the best such letter received during each of the five months of No-

vember, December, January, February and March! (Deadline: Midnight, the last day of each month.)

We will send \$1.00 for every serious letter received so even if you should not win a big prize your time will not be in vain.

Your letter will be our property, of course, and we have the right to reproduce it in a Hallicrafters advertisement.

Good luck and write as many letters as you wish. V-Mail letters will do.

W. J. Holligan



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CHICAGO, U.S.A.

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MAKERS OF THE FAMOUS SCR-299 COMMUNICATIONS TRUCK

BLUEPRINTS OF SAFETY



WEATHER OR NO...

It's a tough job at best...this business of bombing, but around-the-clock it must continue...if we'd shorten the path to victory...and it's during the jittery hours of darkness...or when fog shuts down, that getting home in safety depends on accurate radio transmissions. "Blueprints of Safety" assure that A. A. C. whip-antenna is reliable at all times, and under the most exacting conditions. Its automatic direction finder allocates the course and an additional safety factor is the retractable feature, which facilitates easy replacement from within the ship.

ELECTRONICS DIVISION



AIRCRAFT ACCESSORIES CORPORATION

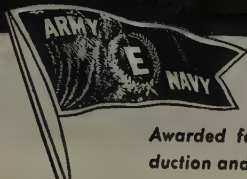
MANUFACTURERS OF

PRECISION AIRCRAFT EQUIPMENT
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DEPENDABILITY AND PRECISION

Superbly engineered . . . mechanically and electrically, DeJur wire-wound potentiometers perform their functions dependably. There's a DeJur potentiometer to fill your needs. Here, we illustrate a few . . . however, we can and do produce these units to required resistances. We will gladly furnish technical data upon request.



Awarded for Excellence in Production and Quality of Material

DeJur-Amsco Corporation
SHELTON, CONNECTICUT

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For Our Uncle!



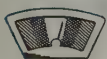
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MALDEN



COMPANY, INC.
MASS., U. S. A.



"It pays to have rigid specifications — eh boys?"...



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TIGHTER THAN CUSTOMER
TOLERANCES**



When measuring aesthetic curves, or when conducting electrical and mechanical tests on vacuum tubes, the more stringent the adherence to accepted standards, the more desirable the resulting selection.

Impracticable as it is to manufacture all tubes of a given type exactly alike, it is possible to insure against slight meter inaccuracies and the human element by

observing specification tolerances tighter than customers' requirements. Each Hytron tube is thus made to fit precisely the circuit constants with which it must operate. For example, strict observance of specifications for grid-to-plate capacitance makes easier the adjustment of tuned circuits to any Hytron tube of the chosen type.

Simplify your design problems for initial and replacement tubes by taking advantage of Hytron's insistence upon close tolerances. Specify Hytron.



OLDEST EXCLUSIVE MANUFACTURER OF RADIO RECEIVING TUBES

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CORPORATION
ELECTRONIC AND
RADIO TUBES
SALEM AND NEWBURYPORT, MASS.





"A SYMBOL

OF YOUR GREAT AND
CONTINUING CONTRIBUTION
TO THE CAUSE OF FREEDOM"



WAR DEPARTMENT
OFFICE OF THE UNDER SECRETARY
WASHINGTON, D.C.

25 September 1943

To the Men and Women
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Chattanooga, Tennessee

I am pleased to inform you that you have won
for the third time the Army-Navy Production Award for
high achievement in the production of war materiel.

In maintaining the fine record which first
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ample for your fellow Americans on the production front.

This second renewal adds a second White Star
to your Army-Navy Production Award flag, and stands as
a symbol of your great and continuing contribution to
the cause of freedom.

Sincerely yours,

Robert P. Patterson
Under Secretary of War

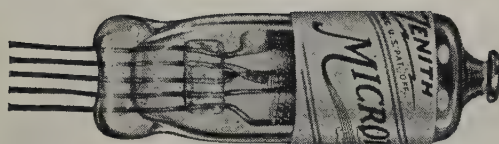
ALSiMAG

TRADE MARK REGISTERED U. S. PATENT OFFICE

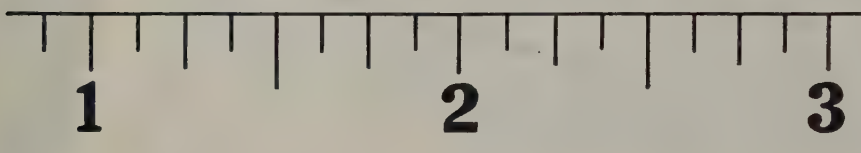
STEATITE CERAMIC ELECTRICAL INSULATION
FOR ELECTRONIC USES

AMERICAN LAVA CORPORATION

ZENITH MICROTUBES



Where space is a factor . . . where power consumption must be at a minimum . . . Zenith Microtubes are recommended . . .



APPLICATIONS

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- Wearable Hearing Aids
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- Beacon Light Relay Circuits
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- Psychiatric Devices
- Light Intensity Meters
- Vacuum Tube Voltmeters
- Aircraft Intercommunication
- Concealed Sound Pickups

A Booklet containing technical data on Zenith Microtubes is available at the factory.

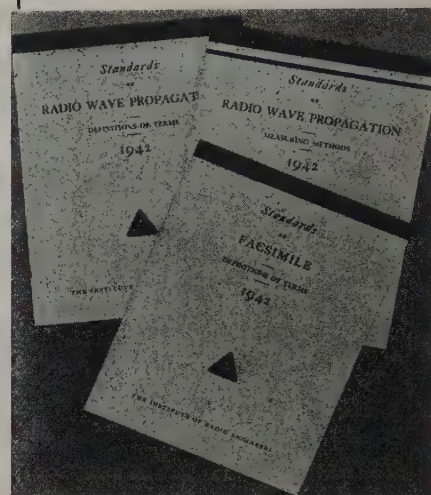
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| 9) American Standard: Standard Vacuum-Tube Base and Socket Dimensions | \$0.20 |
| (ASA C16.2-1939). (8 pages, 7¼×10¾ inches.) | |
| 10) American Standard: Manufacturing Standards Applying to Broadcast Receivers | \$0.20 |
| (ASA C16.3-1939). (16 pages, 7¼×10¾ inches.) | |

Prices are net and include postage to any country. Include remittance with order and address:

**THE INSTITUTE OF
RADIO ENGINEERS, Inc.**
330 West 42nd Street, New York 18, N.Y.



Or should it be 833-A PLUS?

THE RCA 833 became the RCA 833-A long before Pearl Harbor—when important design changes made improved ratings possible.

Now the price is 10% lower—\$76.50 instead of \$85.00 because fine performance has meant wide acceptance, resulting in production economy.

ZIRCONIUM-COATED ANODE: This famous RCA anode gives the 833-A a 44% higher input rating and 33% higher plate dissipation. To a designer, that means wider application possibilities; to a user, it means the 833-A will give longer life than the 833 it replaced.

EMISSION RESERVE: The 100-watt thoriated tungsten filament of the 833-A has a tremendous reserve of emis-

sion. That means less chance of damage in case of unexpected overloads, plus longer filament life.

FILAMENT SHIELDING: The 833-A's plate is specially constructed to shield the filament, thus eliminating bulb bombardment by stray electrons.

FORCED AIR COOLING: Design refinements in the 833-A made it possible for RCA to announce increased ratings when forced-air cooling is used. That means you can increase power by the use of 833-A's instead of 833's—or, you can operate at the same power and run the 833-A's cooler.

TUNE IN "WHAT'S NEW?"

Radio Corporation of America's great new show
Saturday nights, 7 to 8, E. W. T., Blue Network.



Operation with Forced-Air Cooling	Class B A-F CCS* ICAS†	Class C 'Phone CCS* ICAS†	Class C T'graph CCS* ICAS†
Typical Operation			
Plate Volts	4000	3000	4000
Power output, watts	2400	1000	1440
Driving power, watts.....	29	37	26
Max. frequency, Mc:			
at Full input	—	20	20
at 65% input	—	75	75

*Continuous Commercial Service.

†Intermittent Commercial and Amateur Service.



RCA ELECTRON TUBES

RCA Victor Division • RADIO CORPORATION OF AMERICA • Camden, N. J.



SEND FOR THIS BOOK!

For a wealth of information on RCA Transmitting Tubes and how to use them, send 35¢ for the 72-page "RCA Guide for Transmitting Tubes." Write to RCA Commercial Eng. Section, Radio Corp. of America, 538 South Fifth St., Harrison, New Jersey.

ASK ABOUT...





Record Changer.. [The original model]

THIS is the world's most efficient machine, the human hand, designed by the Master Craftsman. Its dexterity and versatility has never been matched mechanically. Yet modern science has found ways to add to the pleasure and comfort of humanity by relieving man's hands of many tedious tasks.

The modern Phonograph Record Changer is an example.

G. I. prewar record changers were conspicuously successful—notable especially for their long, service-free life, the permanence of their factory adjustment and ease of installation.

Our "E" for excellence in war production has accelerated the development of many new methods—new skills—new materials—new skills in the use of these materials. Obviously, you will find such advances in our Post-War record changers.

We believe that effective planning is essential if we are to accomplish a smooth reconversion. We have many plans—some definite—others, embryonic. Would you like to share in our plans? We will be glad to call on you to discuss our future and yours.

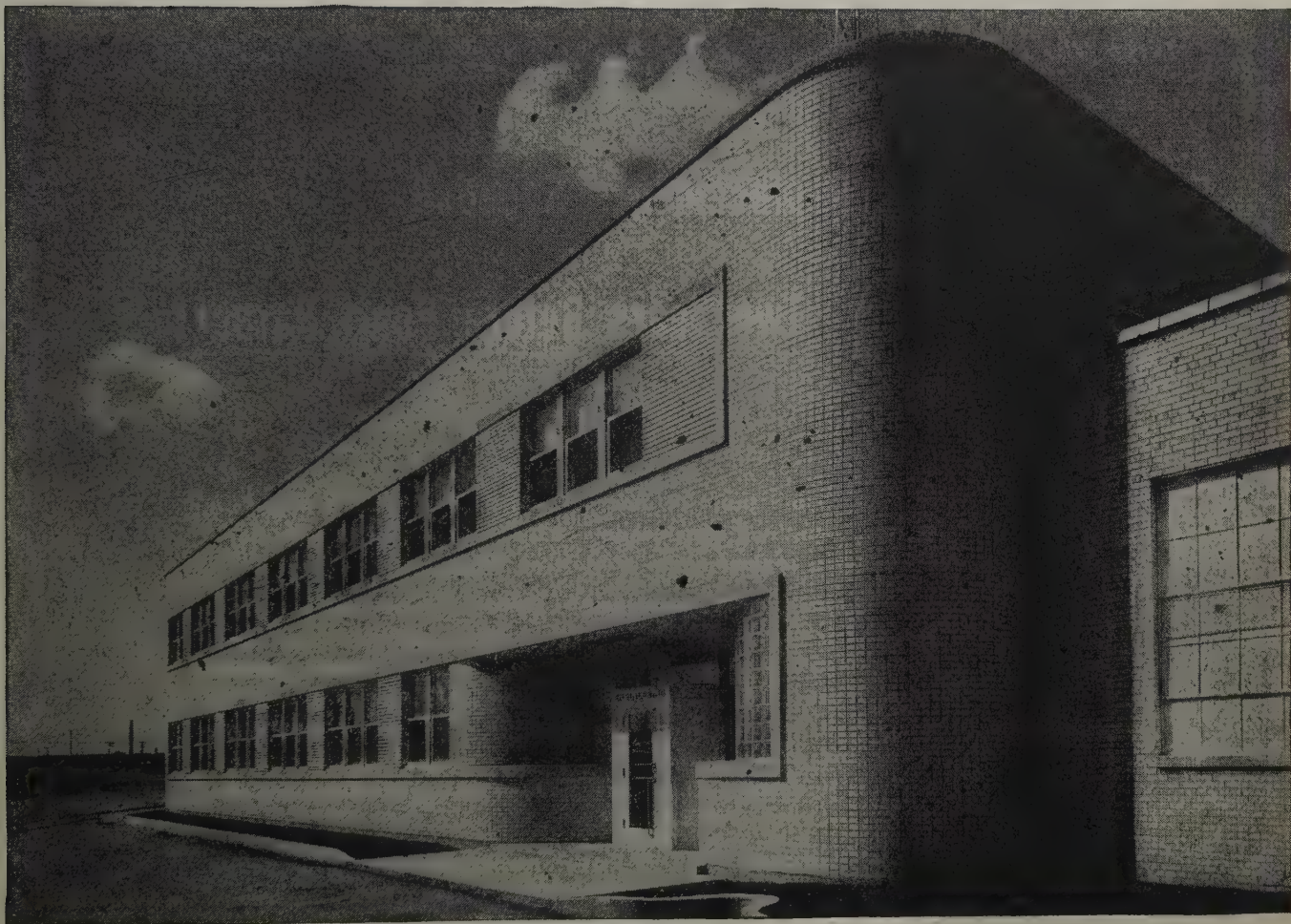


GENERAL INSTRUMENT CORPORATION

829 NEWARK AVENUE, ELIZABETH, N. J.

Electronics...

A CHILD WITH A BIG FUTURE



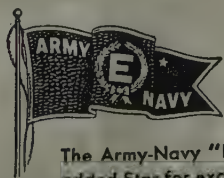
New Motorola Electronics Engineering Building

Another great industry stands at America's threshold . . . and American courage, ingenuity and scientific talents are ready. The new wonders of the Electronic Age stand ready to be revealed to an eager and waiting world.

. . . WITH THE COURAGE OF PIONEERS

Motorola Engineers have faced and solved many important problems in Electronic research and development demanded by the emergency of war . . . and when the time comes, this same tempered and tested brain and brawn will be quickly converted to the needs of peacetime, Victorious America.

You May Expect Important Electronic Contributions from Motorola Engineers. They're in the Making!



The Army-Navy "E" and added Star for excellence in production of Communication Equipment for our Armed Forces.





Today's Replacements Speeded

Two Years Before Pearl Harbor!

- It was more than 23 months before Pearl Harbor that RCA started something which today—23 months after Pearl Harbor—is speeding replacements of electron tubes to far-off fronts.

- For at that time RCA launched its *Preferred Type Tube* program. From among many hundreds of tubes of various kinds and sizes, RCA selected 36 receiving tubes—each for some basic, needed characteristic. This made possible larger manufacturing runs on fewer types, and resulted in better tubes of greater uniformity at lower cost. RCA's program was hailed immediately by equipment manufacturers. They knew that the saving in all-around efficiency would be *their* saving.

- When war came, the U. S. Government also issued a list, called the "Army-Navy Preferred List of Tube Types." (We'll be happy to send you a copy of the latest revised list on request.) And now this program is serving the country well . . . in releasing for other war purposes the stocks of vital materials formerly tied up in the several hundred tube types . . . and in making it possible to expedite delivery of standard type electron tubes wherever the fighting fronts need replacements—*fast*.

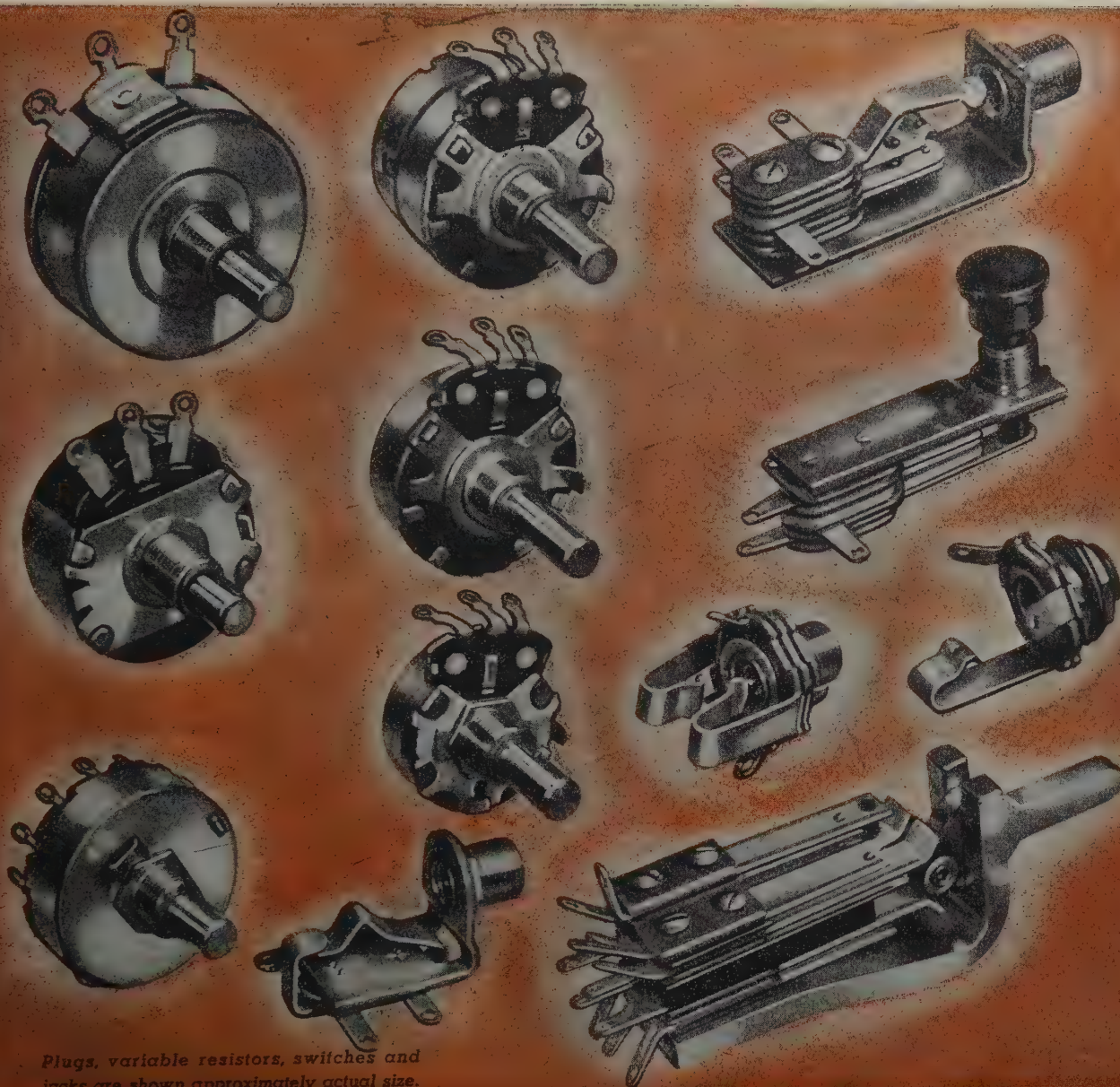
- **POST-WAR POSSIBILITIES.** RCA's application engineers invite inquiries from equipment manufacturers concerning tubes most likely to be on the RCA list of post-war preferred types. Remember: *The Magic Brain of All Electronic Equipment Is a Tube . . . and the Fountain-Head of Modern Tube Development Is RCA.* RCA Victor Division, RADIO CORPORATION OF AMERICA, Camden, New Jersey.



RCA ELECTRON TUBES



TUNE IN "WHAT'S NEW?" RCA's great new show, Saturday nights, 7 to 8, E. W. T., Blue Network.



Plugs, variable resistors, switches and jacks are shown approximately actual size.

Mechanical Components Since 1896

Plugs, Jacks, Switches, Variable Resistors

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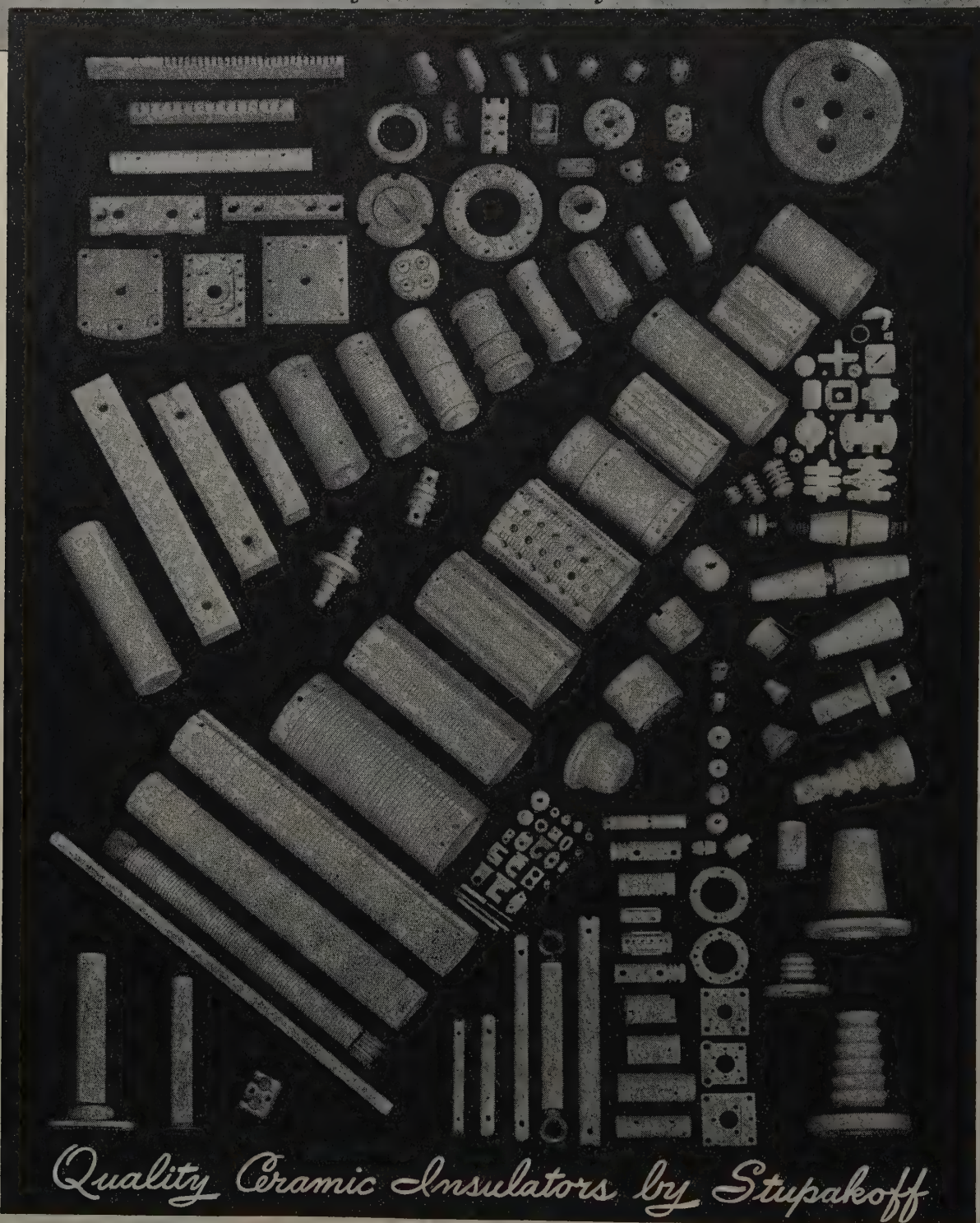
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Manufacturers of Quality Electro-Mechanical Components Since 1896

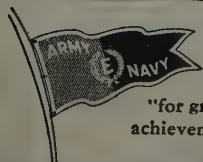
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Ceramics for the World of Electronics

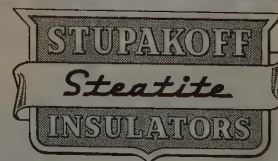


Quality Ceramic Insulators by Stupakoff



Stupakoff produces a complete line of precision, "radio grade", low loss insulators made of Steatite and other materials

Back The Attack—Buy War Bonds



STUPAKOFF CERAMIC AND MANUFACTURING CO., LATROBE, PA.

**SMOOTH HAIR-LINE CONTROL
THROUGH ACK-ACK AND BACK!**



USED in aircraft applications, the AmerTran Airborne RH Transtat Voltage Regulator for 400 Cycle A. C. is a new addition to the already famous Transtat family. It meets the rigid tests of combat aircraft equipment in action.

Like other Transtats, the Airborne RH is a highly efficient transformer type regulator. The velvety smooth Transtat system that controls without circuit interruption is further refined in this newer unit. And, similar to its predecessor, it does not distort wave form or interfere with radio reception. Small, compact, its weight is the minimum achieved for its power rating.

Well suited to incorporation in other electrical equipment where precise line voltage correction or special voltage maintenance is required, its dramatic wartime performance presages a useful peacetime future.

AMERICAN TRANSFORMER COMPANY
178 EMMET STREET, NEWARK 5, NEW JERSEY

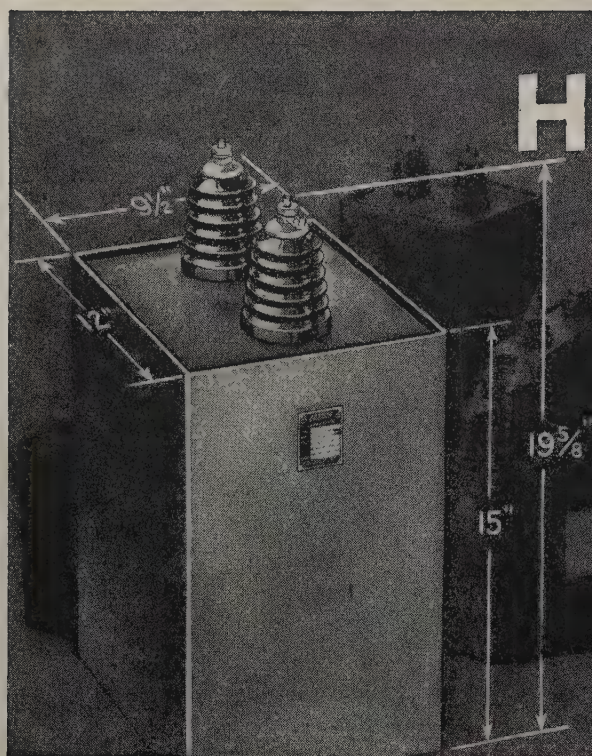
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Transformers, Reactors
and Rectifiers for
Electronics and
Power Transmission**



AMERTRAN

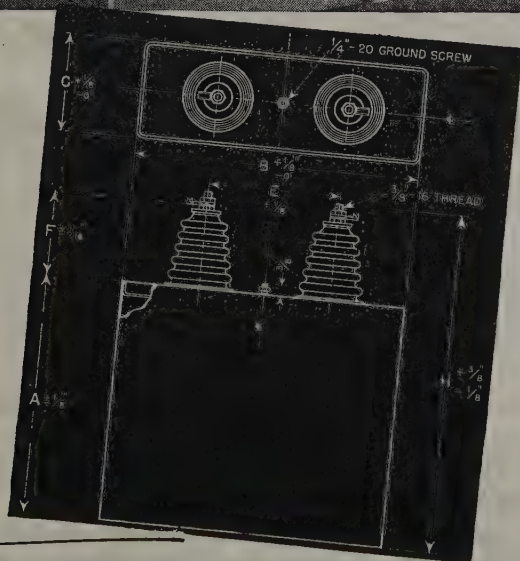
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HIGH-VOLTAGE CAPACITORS



50,000 Volts
FOR INTERMITTENT SERVICE
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To 30,000 Volts
FOR CONTINUOUS SERVICE
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AEROVOX Series '20

TYPE 6020—6000 v. D.C. Work 2.0 mfd. to 10.0 mfd.	0.25 mfd. to 4.0 mfd. TYPE 25020—25,000 v. D.C. Work 0.2 mfd. to 1.0 mfd.
TYPE 7520—7500 v. D.C. Work 0.5 mfd. to 6.0 mfd.	TYPE 37520—37,500 v. D.C. Work 0.1 mfd. to 1.0 mfd.
TYPE 10020—10,000 v. D.C. Work 1.0 mfd. to 5.0 mfd.	TYPE 50020—50,000 v. D.C. Work 0.1 mfd. to 0.5 mfd.
TYPE 12520—12,500 v. D.C. Work 0.5 mfd. to 5.0 mfd.	also 25,000 v. Output (12,500—12,500 v.) for Voltage-Doubler Circuits
TYPE 15020—15,000 v. D.C. Work 0.25 mfd. to 3.0 mfd.	0.25-0.25 mfd. to 0.5-0.5 mfd.
TYPE 20020—20,000 v. D.C. Work	

● To meet certain radio and electronic requirements, Aerovox engineers have developed the Hyvol Series '20 oil-filled capacitors covering voltage ratings from 6000 to 50,000 v. D.C.W. Already many of these capacitors are in military service.

Giant Aerovox designed and built, winding machines handle up to several dozen "papers." Likewise a battery of giant tanks permits long pumping cycles for thorough vacuum treatment, followed by oil impregnation and filling, of the sections. The multi-laminated kraft tissue and hi-purity aluminum foil sections are uniformly and accurately wound under critically controlled tension to avoid mechanical strain.

The sections are connected directly across the full working voltage. In the higher capacity units, a plurality of sections are connected in parallel. These capacitors are not to be confused with the series-connected sections heretofore frequently resorted to in attaining high working voltages. Sections are hermetically-sealed in sturdy welded-steel containers. Rust-proof lacquer finish. Cork-gasketed pressure-sealed glazed porcelain high-tension pillar terminals.

● Regardless whether it be giant high-voltage capacitors or a low-voltage by-pass electrolytic, send that problem to us for engineering collaboration, recommendations, quotations. Catalog on request.

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Capacitors

INDIVIDUALLY TESTED

The Rubber Plant

**with roots
two miles deep!**

THE MAKING OF synthetic rubber involves among other things the exact control of gas mixtures of great complexity. Formerly the analysis of some gases required several days of painstaking laboratory work, and in some cases a complete analysis was impossible.

Westinghouse scientists—working in close collaboration with engineers of leading oil and chemical companies—have perfected an electronic “chemist” which is an important addition to the present methods of analysis.

With the improved technique and apparatus now available, the time required for accurately making some of these analyses has been reduced to *an hour or less!*

An amazing electronic device . . . known as the mass spectrometer . . . not only improves the accuracy of the synthetic rubber process, but frees hundreds of skilled chemists from tedious but important production testing in these vital plants.

The mass spectrometer analyzes gases by sorting the molecules—according to their mass—in (roughly) the same way that a cream separator sorts out the cream from whole milk.

Let's say we want to analyze a simple gas mixture containing *one part* of oxygen and 10,000 parts of nitrogen. Here's how the mass spectrometer accomplishes this incredible feat:

First, the gas sample is bombarded

with electrons. This ionizes the nitrogen and oxygen molecules, giving them electrical charges of their own.

These ions are then drawn by electrical force into a curved vacuum tube. Here, ions of different molecular weights whizz around *different curved paths*—depending upon their reaction to a powerful electromagnet surrounding the tube.

The heavier oxygen ions follow a straighter path than the lighter nitrogen ions and are directed through a tiny exit slit onto a plate where they give up their electrical charge. The amount of this charge, amplified and recorded by sensitive electrical instruments, is an extremely accurate measure of the *quantity*

of oxygen in the gas mixture.

The starting voltage is then changed to allow the nitrogen ions to pass through the same exit slit—thus measuring the *quantity of nitrogen*. This same principle applies to the analysis of complex hydrocarbon mixtures.

The development of the mass spectrometer . . . for the quick, accurate analysis of butadiene . . . is a typical example of the way Westinghouse “know how” in electronics is tackling the wartime problems of industry in an effort to speed victory.

Westinghouse Electric & Manufacturing Company, Pittsburgh, Pennsylvania.



Westinghouse

PLANTS IN 25 CITIES OFFICES EVERYWHERE

PLEASE LIMIT YOUR CALL TO FIVE MINUTES

When a Long Distance circuit is crowded the operator will say: "Please limit your call to five minutes."

Observing this time limit on essential calls, and avoiding all unnecessary calls, will help the whole war effort.



BELL TELEPHONE SYSTEM



★ BUY MORE WAR BONDS

RCA-2050... *the Thyatron that started a new trend in electronic control*



A THYATRAN is a "trigger" tube—a grid-controlled rectifier—which can "switch" power from full OFF to full ON with a very small change in control voltage.

The RCA-2050, announced in 1939, was a great step forward in thyatron design because it combined unusually high stability and great sensitivity.

Its characteristics were more uniform, too—from one tube to another, from one temperature to another, and throughout the life of any one tube.

Because the RCA-2050 offered such unusual performance, it quickly became a favorite tool of electronics engineers.

And it still is!

Here is a Summary of RCA-2050's Advantages

1. **Stability Throughout Life.** Characteristics of 2050 change relatively little throughout life of tube.
2. **High Power-Sensitivity.** Extremely low grid current (less than 0.1 microampere) permits use of high value grid resistor (up to 10 megohms) with consequent high sensitivity. RCA-2050 can be operated directly from a high-vacuum phototube.
3. **Little Affected by Line-Voltage Surges.** Stability as affected by line voltage surges is high because of the low grid-anode capacitance which results from the use of a shield grid.
4. **Extreme Temperature Range.** RCA-2050 is unaffected by temperature changes over the range of -50°C to $+65^{\circ}\text{C}$!
5. **All-position Mounting.** You can mount the 2050 in any position since it is gas filled and contains no mercury. Its position can be changed during operation.
6. **Low Voltage Drop.** Xenon filling provides a tube drop of only 8 volts.
7. **Quick Warm-up.** Ready for operation in 10 seconds after heater is switched on.
8. **Low Cost.** List price of RCA-2050

is now \$1.35, a 62% reduction from its original price.

9. Army-Navy Preferred Type Listing.

Application

The 2050 has found wide application in industrial control circuits. Its high power-sensitivity has made it invaluable as a link between actuating circuits and power circuits eliminating amplifier stages and sensitive relays.

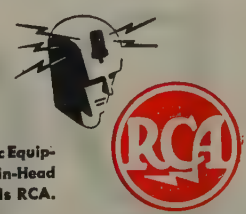
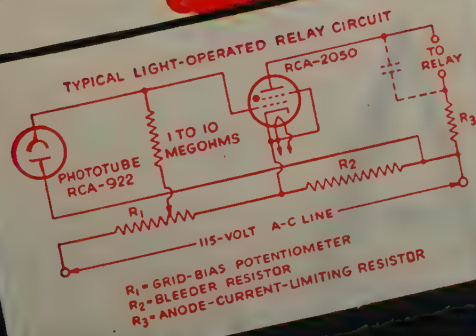
The stability of the 2050 makes possible a high degree of accuracy in timing circuits.

The RCA-2050 is extensively used in control circuits for positioning, for welding, for air-doffer operation, for plastic molding, and as a relay tube in phototube control circuits.

If you have an application problem, RCA application engineers may be able to help you. Write, stating your problem, to Radio Corporation of America, Commercial Engineering Section, 527 South Fifth Street, Harrison, New Jersey.

Technical Data

Heater volts, 6.3; heater amperes, 0.6; grid-to-anode capacitance, $0.2\mu\text{f}$; heating time, 10 seconds; maximum overall length, $4\frac{1}{2}$ inches; base, small shell octal 8-pin; peak forward anode volts, 650; peak inverse anode volts, 1300; average anode milliamperes, 100; tube voltage drop, 8 volts.



The Magic Brain of All Electronic Equipment is a Tube and the Fountain-Head of Modern Tube Development is RCA.

TUNE IN "WHAT'S NEW?" RCA's great new show, Saturday nights, 7 to 8, E. W. T., Blue Network.

RCA ELECTRON TUBES



They Won't Forget "Rola"

RIGHT now manufacturers of war materials can be making friends for tomorrow's products, products that do not yet exist . . . that may not even have reached the blueprint stage. For if what a Company makes for War gives good account of itself, isn't there likely to be a greater confidence in the Company's peacetime products?

Take Rola for example. In leading factories throughout the country skilled mechanics are building thousands of communications systems for the Army-Navy Air Forces . . . using various important parts made by Rola. In countless places all over the world technically trained military personnel are installing and maintaining these systems, again with Rola equipment.

When their wartime job is done, most of these men will continue in their chosen field and will occupy positions of importance and influence in all branches

of Radio and Electronics. We firmly believe that into their peacetime jobs these same men will carry the highest regard for everything that bears the name "Rola", a regard born of the first-hand knowledge that a Rola product . . . whatever it may be . . . is a Quality product.

At least we can think of no way to make more certain "they won't forget Rola", than to continue to provide the very best equipment it is possible to make. THE ROLA COMPANY, Inc., 2530 Superior Avenue, Cleveland 14, Ohio.

New applications constantly are being found for Rola's diversified equipment and broad manufacturing experience. If your production problems involve anything related to our field, we believe you should see what Rola has to offer.

ROLA

MAKERS OF THE FINEST IN SOUND REPRODUCING AND ELECTRONIC EQUIPMENT

A TYPE FOR IMPORTANT NEEDS



STYLE "K" RESISTORS: Power Wire Wound Resistors 5, 10, 25, 50, and 120 watts.

Wire lead or lug terminals on styles 5K and 10K.

Lug terminals only on styles 25K, 50K, 120K.

Non-inductive windings available.

Various types of mounting, shown in catalog.

STYLES A, B, C, D, E, F: 120, 90, 50, 35, 20, 10 watts.

Hermetically sealed power wire wound resistors. Designed to withstand salt water immersion tests.

Ferrule Terminals for fuse clip mounting.

Non-inductive windings available.

STYLE V. D.: 10 watt and 15 watt wire wound. Resistors designed to make voltage divider sections when mounted end to end on through bolt.

STYLES MFA, MFB and MFC: Precision Meter Multiplier Resistors. Hermetically sealed. Salt water immersion proof.

Type MFA—7.5 megohms max.

Type MFB—4 megohms max.

Type MFC—1 megohm max.

STYLE SP: Wire wound bobbin type resistors. Style SP-1, single section. Style SP-2, dual section.

2.5 watts, continuous rating, per section.

250,000 ohms max. per section.

MEGOMAX: High voltage, high temperature, composition resistor. Hermetically sealed.

Type 1—3400 ohms to 100 megohms

Type 2—6800 ohms to 100 megohms

Voltage and power ratings depend on resistance value.

SPRAGUE SPECIALTIES CO., Resistor Division, NORTH ADAMS, MASS.

SPRAGUE KOOLOHM RESISTORS

REGISTERED TRADEMARK



IT'S STILL ✓ *Check*
and ✓✓ *Double Check*

for EACH and EVERY DuMONT TUBE

▶ A thousand cathode-ray tubes are produced in the DuMont plant today where but a dozen were made before. Yet each and every DuMont tube continues to be meticulously checked for operating characteristics. Mass testing, without slightest deviation from critical DuMont standards, must match today's mass production.

And so DuMont engineers have developed and built the all-the-answers-at-a-glance test positions here shown. Tubes plug into corresponding receptacles and rest on the inclined shelf. Power supply voltages are adjusted for given tubes. Meters indicate circuit

and operating conditions.

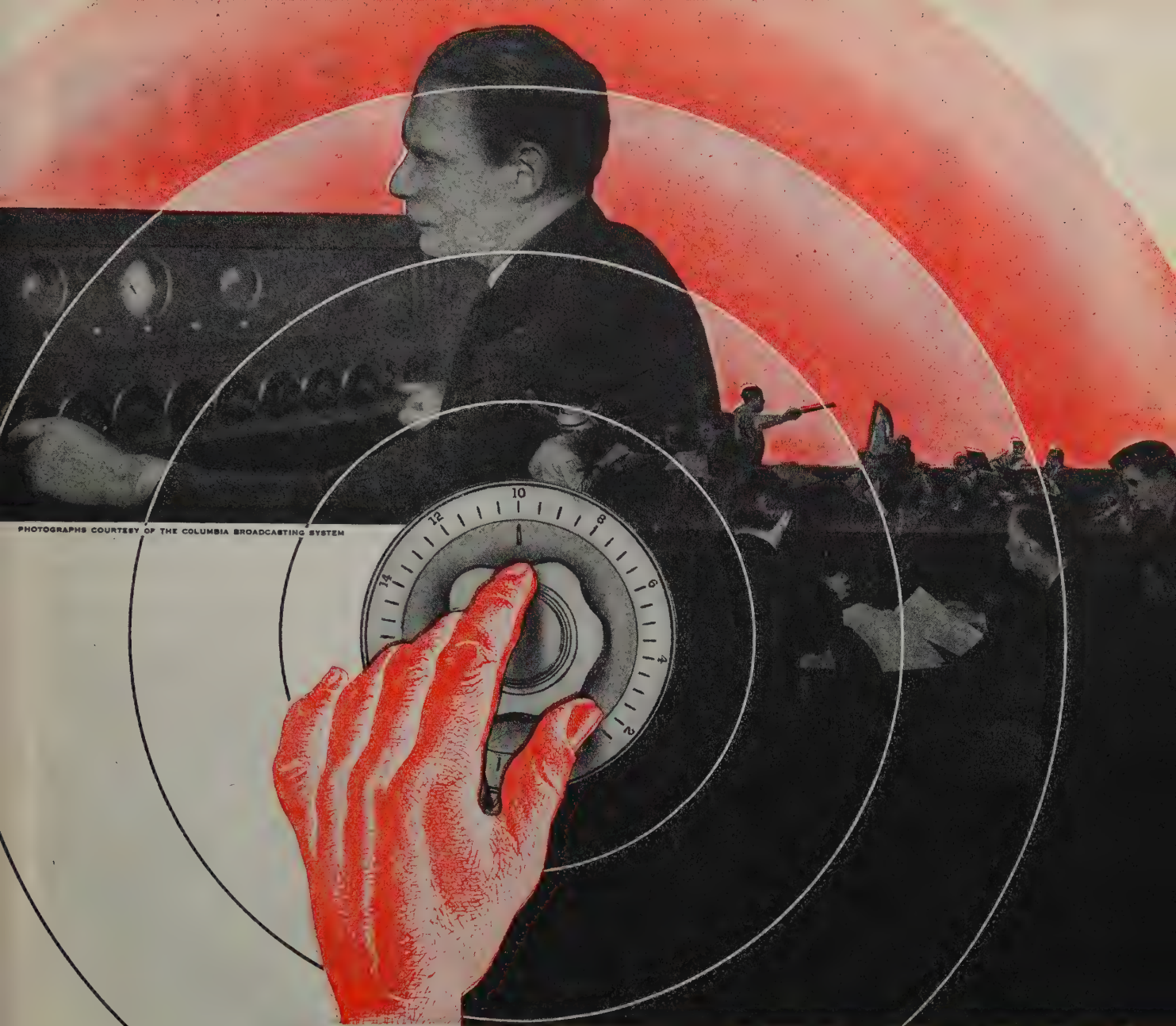
Sitting at the comfortable "electronic desk", the operator checks for brilliance, focus, deflection, leakage resistance and other characteristics—simply, quickly, positively. Meanwhile, a generous and representative percentage of each production run goes to life test racks so that anticipated service life is an established fact rather than a mere guess.

Check and double check—this DuMont test routine day in and day out, regardless of enormously stepped-up production, continues to safeguard an enviable performance record.

▶ The new DuMont loose-leaf manual and catalog is now available. Write on business stationery for your registered copy.



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LABORATORIES, Inc.**
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PERFORMANCE . . . THE PRIME CONSIDERATION

DAVEN attenuators are preferred wherever precision and quality are required. Verification may be found in the control rooms of the major broadcasting chains—NBC, CBS, Mutual, Blue—as well as in leading stations, both here and abroad. Where performance is the prime consideration, DAVEN components are included in standard and special equipment. In the hands of engineers whose judgement is seasoned, they provide precise and dependable control.

DAVEN produces the most complete line of precision attenuators in the world in addition to more than 80 models of laboratory test equipment for the broadcast, sound picture, television, and electrical fields. A DAVEN catalog should be in your files.

HELP SHORTEN THE WAR . . . KEEP BUYING MORE WAR BONDS

THE DAVEN COMPANY

191 CENTRAL AVENUE

NEWARK 4, NEW JERSEY



PRECIOUS CARGO

Aboard the ECA ship of the future... manned by our creative engineers... is a precious cargo of electronic techniques adaptable to postwar living. At present, however, our total efforts are pointed toward the liquidation of the Axis. We are supplying vital equipment to the Armed Services at a faster rate to help shorten the war. More than two decades of radio and electronic specialization are recorded in our laboratory's "log"... and the many practical developments, borne of past commercial and current wartime experiences, will be made available to you. From time to time, our present schedules permit us to accept additional assignments.

FORMULA FOR GREATER PRODUCTION

... cordial management-labor relations, good working conditions, recognition of individual merit, incentive-bonus plan, recreational and educational facilities, and the will to get the war over in a hurry.



ELECTRONIC CORP. OF AMERICA

45 WEST 18th STREET • NEW YORK 11, N. Y. • WATKINS 9-1870



VIBRATION TESTED

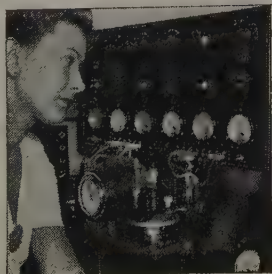
Long before the war, TUNG-SOL established the practice of "Vibration-Testing" all radio tubes of new design and tubes picked out at regular intervals from the production line. Making tubes that meet government standards was nothing new.

Today the TUNG-SOL Radio Tubes in communication equipment of jeeps and planes and tanks and in portable sending and receiving sets are subjected to far more severe conditions than will ever be

encountered in civilian uses. TUNG-SOL Tubes are giving praiseworthy performances... a direct result of "Vibration-Testing."

Manufacturers of electronic devices and of electronically controlled equipment will find TUNG-SOL a most satisfactory source of dependable tubes for every application. TUNG-SOL research engineers will be glad to assist you now in making your post-war products more efficient through Electronics.

Current is introduced through the various circuits of the tube while it is being rapidly vibrated. Uniformity of the current flow is indicated by sensitive meters and is positive proof of proper design and construction. Tubes that pass this most exacting test are truly classed as "VIBRATION-TESTED."



TUNG-SOL
vibration-tested
RADIO TUBES

TUNG-SOL LAMP WORKS INC., NEWARK, N. J., Sales Offices: ATLANTA, CHICAGO, DALLAS, DENVER, DETROIT, LOS ANGELES, NEW YORK
ALSO MANUFACTURERS OF MINIATURE INCANDESCENT LAMPS, ALL-GLASS SEALED BEAM HEADLIGHT LAMPS AND CURRENT INTERMITTERS

WANTED

for the

PHILCO ENGINEERING STAFF

● RADIO—ELECTRONICS—ELECTRICAL ENGINEERS

Men with degrees in electrical engineering or comparable experience in radio and television.

● MECHANICAL ENGINEERS

Men with college degrees or comparable experience in the engineering aspects of electrical appliances, and in designing small machinery.

● DESIGN ENGINEERS — DRAFTSMEN

Men with experience in mechanical designing, especially of small metal parts and of the automatic machinery to mass-produce them.

● PRODUCTION ENGINEERS

Including electrical and mechanical engineers familiar with any phase of radio, radio-phonograph and television production.

● PHYSICISTS

Must have science degree in physics. Some practical experience in radio is desirable.

WE expect the men who qualify for these positions to become permanent members of our staff and take an important part in our post-war program.

To maintain the Philco tradition of progressive research and development, is first and foremost in our minds. We provide the finest of technical equipment. But often, even more helpful is the inspiration and personal assistance of working with men who have done so much for the advancement of Radio, Television, Refrigeration and Air-Conditioning.

WRITE US TODAY

Qualified men not now engaged in work requiring their full talents, are invited to write us in detail as to their experience, education, family and draft status, and salary. Letters will be treated in strict confidence.

Employment subject to local W.M.C. rules.

WRITE TO MR. GEORGE DALE

PHILCO CORPORATION

Philadelphia 34, Penna.



The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No.

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.

330 West 42nd Street, New York 18, N.Y.

RADIO ENGINEER

Experienced in the manufacture and testing of ultra-high-frequency apparatus; must be capable of taking complete charge of war projects. Splendid opportunity. War workers at highest skill need not apply.

Inquiries will be kept confidential. Please state age, experience and salary expected. Write Box 288.

ELECTRICAL AND RADIO DESIGN ENGINEERS

Familiar with analysis and design of complex circuits similar to those used in radio transmitter equipment. Should have five years full-time commercial or research experience. Must have B.S. in E.E., or equivalent; thorough grounding in engineering electronics and familiarity with high-voltage rectifier systems. Apply in writing, to Personnel Office, Radiation Laboratory, University of California, Berkeley, California.

RADIO TECHNICIAN

In Brooklyn war plant. Must be able to use test equipment, to set up and use laboratory test instruments and supervise production testing of radio parts and electronic equipment. Will consider men with amateur radio experience. State age, education, experience. Availability certificate required. Write to Box 308.

ELECTRONIC TUBE DESIGN ENGINEER

Experience in actual design and manufacture of large high-vacuum tubes, or electrical and mechanical design, as well as in process, test, and application techniques. Essential workers need release statement. Write to Box 309, giving complete details including salary expected.

ELECTRONIC DESIGN ENGINEERS

One of the largest manufacturers of radio equipment, located in Eastern Massachusetts, has openings for several engineers. Work involves design and development of electronic apparatus having a wide field of application both now and after the war.

A Master's degree, or a B.S. degree in Electrical Engineering with two years' experience in electronic work, would be desirable but not absolutely necessary, depending upon the individual. Those now employed in an essential activity must be able to obtain release. Applicants should submit their qualifications and salary expected to Box 307.

RADIO ENGINEERS AND TECHNICIANS

A progressive company with a sound background in radio and electronics needs, at once, several men with training and experience in any phase of the radio industry. The work open is vital to the war effort but offers a promising post-war future for the right men. College degree or equivalent experience necessary. Men now engaged at highest skill on war production should not apply. Write Box 294.

INSTRUCTORS IN ELECTRICAL ENGINEERING

Instructors in Electrical Engineering needed to teach civilians and A.S.T.P. trainees in Electrical Engineering, in prominent Eastern university. Work will be mostly in communications, some power, and in the Electrical Engineering laboratories. Basic salary \$2400-3200. Opportunity for advancement. Box 310.

(Continued on page 51A)

WANTED

Electrical and radio design engineers, familiar with analysis and design of complex circuits similar to those used in radio transmitter equipment. Should have year's full time commercial or research experience. Must have B.S. in Electrical Engineering, or equivalent, thorough grounding in engineering electronics and familiarity with high voltage rectifier systems.

APPLY IN WRITING

Personnel Office

Radiation Laboratory

University of California

Berkeley, California

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There are only a few of the sort we want. They're engineers . . . men with a solid, expert background in electronic design . . . men who aren't hidebound in their thinking.

We offer them an unlimited future in a new scientific industry now working at full capacity on military devices. We want their expert talents to help us explore even further the peacetime possibilities of this new science.

It's a big job. It needs big men. If you think we're talking to you, write us your whole story and enclose a photo. Please don't phone or call until an appointment has been set up for you.



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(Continued from page 50A)

ELECTRICAL OR CHEMICAL ENGINEER

... thoroughly versed in the theory of liquid and solid dielectrics for the position of chief engineer. To direct the research, development and general laboratory on capacitors and capacitor applications. This is an unusual opportunity for a capable engineer interested in his present and postwar future. Write to Industrial Condenser Corp., 1725 W. North Ave., Chicago, Ill.

RADIO ENGINEERS

Transcontinental & Western Air, Inc. has openings at Kansas City for three Radio Engineers in the Communications Department. Applicants should have completed an electrical or radio engineering course, or should have had one to two years of practical experience. These openings are permanent.

For additional details and application forms, write to Personnel Department, Transcontinental & Western Air, Inc., Kansas City, Missouri.

PATENT ATTORNEYS

Patent attorneys, who are electronic physicists and electrical or radio engineering graduates who have maintained contact with the field of high-frequency electronics, radio manufacture, carrier-current telephony, and light-current circuit design and computing, can make a substantial contribution in research or development jobs with one of the National Defense Research Committee laboratories located in the East. The project is secret but is one of the most urgent of all research jobs now under way for the Government.

An electrical engineering background in light currents is essential, and amateur radio experience, inventive ability and ingenuity in the design and layout of radio equipment would be of considerable help.

Facilities for specialized refresher training and orientation in the particular field may be available. Anyone who possesses these qualifications and is interested in a vital wartime development job for the duration may get further details on request. All inquiries will be held confidential. Address Box 299.

ELECTRONIC ENGINEER

Electronic engineer with M.A., Ph.D., or the equivalent in physics, for research and design in geophysics. Experience in filter design and sound recording is desirable. Write to Independent Exploration Company, 901 Esperson Building, Houston, Texas.

ENGINEER

AAA-1 eastern manufacturer, over 75 years operation and leader in growing industry, has immediate permanent position for chemical, electrical, electronic or chemical-metallurgical engineer to organize and increase efficiency of production activities. Send full details of experience to Box 301.

RADIO OR ELECTRICAL ENGINEER

Capacitor manufacturer located in New Bedford, Mass., wants an electrical or radio engineer—man or woman—for equipment- and circuit-development work.

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Applicant should be college graduate with a degree—or equivalent experience—in radio engineering or electrical engineering.

Interview in Boston, New Bedford or New York can be arranged. Traveling expenses paid to place of interview.

Write fully, giving age, education, experience, etc. Address reply to Box 302.

RADIO ENGINEERS

Well-established international corporation, 100% in war work with definite postwar possibilities, needs several radio engineers who are familiar with the construction or use of automatic-receiving equipment. Also two transmitter engineers familiar with 40 k.w. equipment.

Applicants should have college degree or approximately ten years experience in radio. Openings in Chicago and New York. Salaries from

(Continued on page 52A)

CREI Training Increases Technical Efficiency

*Alert Engineers are encouraging
CREI training for their employees
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Yes, men who devote their own money and spare-time toward improving their technical ability through CREI training are an asset to any technical organization.

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RADIO ENGINEERS and Physicists with an Eye to the Future

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ELECTRONIC ENGINEER—To work on the design and development of electronic devices. Prefer man with about five years radio engineering experience. Must have good grounding in U.H.F. Should be either an electrical engineer or physics graduate.

ELECTRONIC ENGINEER—To work on the development and production of special products as well as aid in devising types of equipment to be used in their manufacture. Previous radio tube experience desirable but not essential. Prefer graduate electrical engineer or physicist.

FACTORY ENGINEER—To work on factory production and shrinkage problems and supervise the processing of items relative to the manufacture of radio tubes. Electrical engineering or Physics graduate preferred.

In addition to the above positions we have a few other openings for engineers and physicists, who are interested in the design, development and production of radio tubes and electronic devices and equipment.

If you would like to participate in developments that will later play a vital part in raising the American Standard of Living, won't you send us enough information about your technical education, training and experience and salary requirements to warrant an early interview.

SYLVANIA ELECTRIC PRODUCTS INC.

Industrial Relations Department
254 Essex Street, Salem, Massachusetts



(Continued from page 51A)

\$100.00 a week dependent upon experience and ability.

In reply please give complete details of experience, age, education, present and former employers, present earnings and your telephone number. Enclose recent photo if available. Address reply to Box 303.

RADIO ENGINEER

EDUCATION: Minimum of two years college in Electrical Engineering.

EXPERIENCE: Minimum of two years in radio test or engineering, or five years in electrical control work (power station or telephone central-office wiring, etc.).

Must be of a type qualified to interpret and clarify with inspectors and responsible executives electrical specifications, problems of manufacture, test and inspection. Address Box 290.

RADIO AND ELECTRONIC ENGINEERS

First, we are seeking the services of one or two trained engineers who have had ample experience in electronic engineering. The men selected will not only be concerned with present war production, but should eventually develop key positions in postwar operation.

Second, we are also looking for a few young engineers who have had good schooling and background to be trained for specialized work with us.

This is an excellent opportunity for men who qualify to connect with a progressive, highly regarded manufacturer of transmitting tubes. Many special benefits will be enjoyed in your association with this company.

Write at once giving complete details of past experience. Interviews will be promptly arranged. Persons in war work or essential activity not considered without statement of availability. Chief Engineer, United Electronics Company, 42 Spring Street, Newark, New Jersey.

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Leading manufacturer of industrial radio-frequency equipment desires the services of a physicist or electrical engineer to direct developmental and applications laboratory. This field is expanding rapidly and offers excellent opportunities for advancement. Position of a permanent nature. Present activities devoted entirely to the war effort. Address replies to Box 306.

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Openings exist for sound and projection engineers. Several years experience in the installation and maintenance of 35 mm motion-picture equipment of all types required. Must be draft exempt or over draft age and free to travel anywhere in the United States. Basic starting salary \$3200. U. S. Army Motion Picture Service, Engineering and Maintenance Division, 3327-A Locust Street, St. Louis, Missouri.

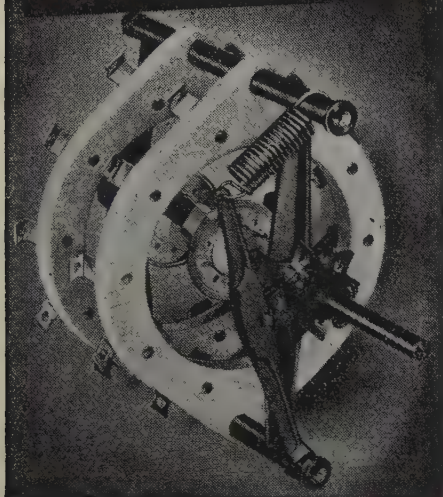
RADIO ENGINEERS

Permanent radio-engineering position in Southern California for men with creative and design aptitude, especially with UHF circuits. Starting salary and advancement depends upon the engineer's experience and ability.

Applications are solicited from persons that are not using their highest skills in war work. Write complete qualifying educational training and experience to Chief Radio Engineer, Bendix Aviation, Ltd., in care of The Shaw Company, 816 W. 5th Street, Los Angeles 13, California.

The foregoing positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No.

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Type 88S-2-gang Sterling Switch

Mechanical ruggedness is not enough for today's switch applications. That is why all conducting paths in STERLING SWITCHES are made of *pure silver*—not plating. So "rugged" are the electrical characteristics of this newest development of Communication Products that the electrical life of the STERLING SWITCH is as long as its mechanical life.

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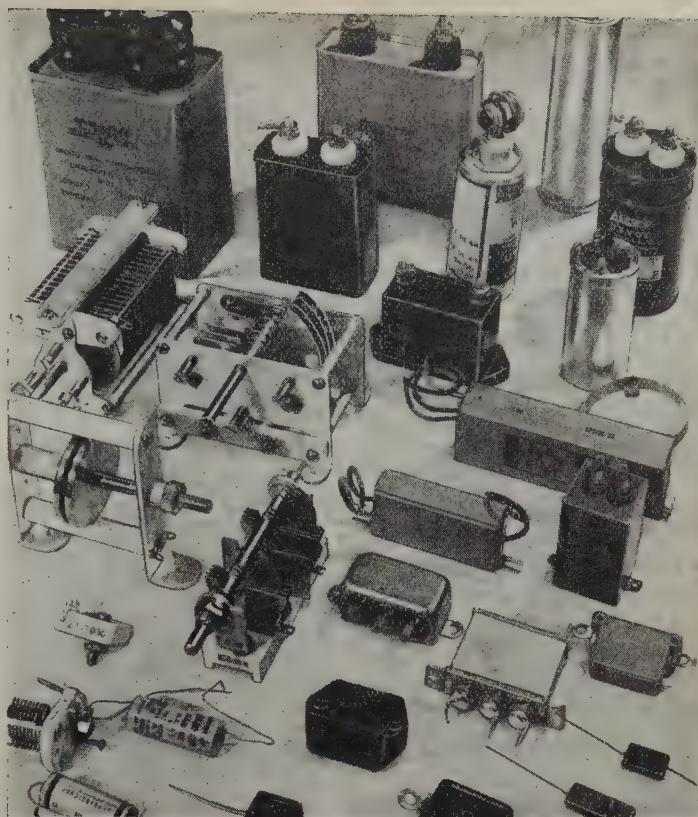
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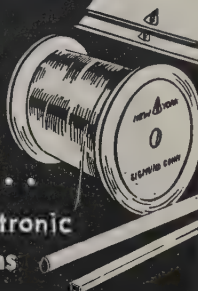
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INDEX

I.R.E. People	34A
Section Meetings	40A
Membership	42A
Incorrect Addresses	48A
Positions Open	50A
Television Relay Network	58A

DISPLAY ADVERTISERS

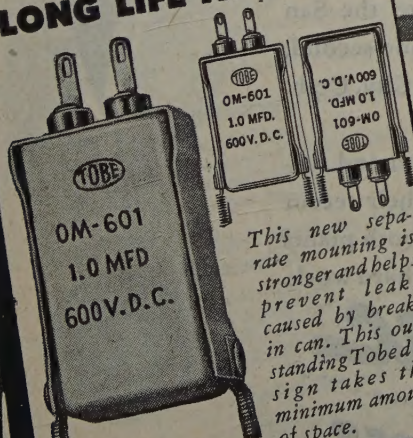
Aerovox Corporation	33A
Allen-Bradley Company	45A
Alliance Mfg. Company	36A
American Lava Corporation	23A
American Telephone & Telegraph Co.	12A
American Transformer Company	17A
Amperex Electronic Products	21A
Andrew Company	56A
Arnold Engineering Company	54A
Audio Development Company	40A
Bell & Howell Company	50A
Bliley Electric Company	34A
Browning Laboratories, Inc.	30A
Capitol Radio Engineering Institute	51A
Centralab	31A
Chicago Transformer Corp.	59A
Cineadagraph Speakers, Inc.	58A
Clarostat Mfg. Company, Inc.	57A
Sigmund Cohn & Company	64A
Communication Products Co.	63A
Connecticut Telephone & Elec. Div.	62A
Continental Electric Company	44A
Cornell-Dubilier Electric Corp.	Cover III
Corning Glass Works	4A, 5A
Daven Company	15A
DeJur-Amsco Corporation	22A
Tobe Deutschmann Corp.	65A
Dial Light Co. of America, Inc.	58A
Allen B. DuMont Laboratories, Inc.	6A
DX Crystal Company	52A
Eicor Inc.	57A
Eitel McCullough, Inc.	66A
Elastic Stop Nut Corp. of America	28A
Electronic Corp. of America	16A
Electronic Laboratories, Inc.	Facing 17A
Electronic Mechanics, Inc.	25A
Electro-Voice Mfg. Co., Inc.	3A
Erwood Company	64A
General Electric Company	53A
General Radio Company	Cover IV
Hallcrafters Company	2A
Harvey Radio Laboratories, Inc.	54A, 57A
Heintz & Kaufman, Ltd.	37A
Hytron Corporation	29A
Industrial Condenser Corp.	38A
International Resistance Co.	35A
Jackson Electrical Instrument Co.	46A
James Knights Company	26A
Lafayette Radio Corp.	47A
Littelfuse Inc.	55A
Measurements Corporation	61A
Merit Coil & Transformer Corp.	60A
Mycalex Corp. of America	8A
National Company, Inc.	10A
National Union Radio Corp.	13A
North American Philips Company, Inc.	24A
Operadio Manufacturing Company	64A
Philco Corporation	50A
Pioneer Gen-E-Motor	61A
Radio Corp. of America, Victor Div.	9A, 32A, 43A
Radio Specialties Co.	63A
Rauland Corporation	18A
Raytheon Manufacturing Company	27A
Remler Company, Ltd.	53A
Rola Company	Facing 16A
Shallcross Mfg. Company	55A
Solar Manufacturing Corp.	19A
Sprague Specialties Company	14A
Standard Transformer Corp.	42A
Stupakoff Ceramic & Mfg. Company	20A
Sun Radio & Electronics Company	51A
Superior Electric Company	60A
Sylvania Electric Products, Inc.	39A, 52A
Templetone Radio Company	51A
Terminal Radio Corporation	63A
Thordarson Elec. Mfg. Company	48A
Triplett Electrical Instrument Co.	56A
Tung-Sol Lamp Works, Inc.	49A
United Transformer Company	Cover II
Universal Microphone Co. Ltd.	59A
University of California	50A
Utah Radio Products Company	41A
Walker-Jimieson, Inc.	63A
Westinghouse Elec. & Mfg. Co.	7A
Wilcox Electric Company	11A

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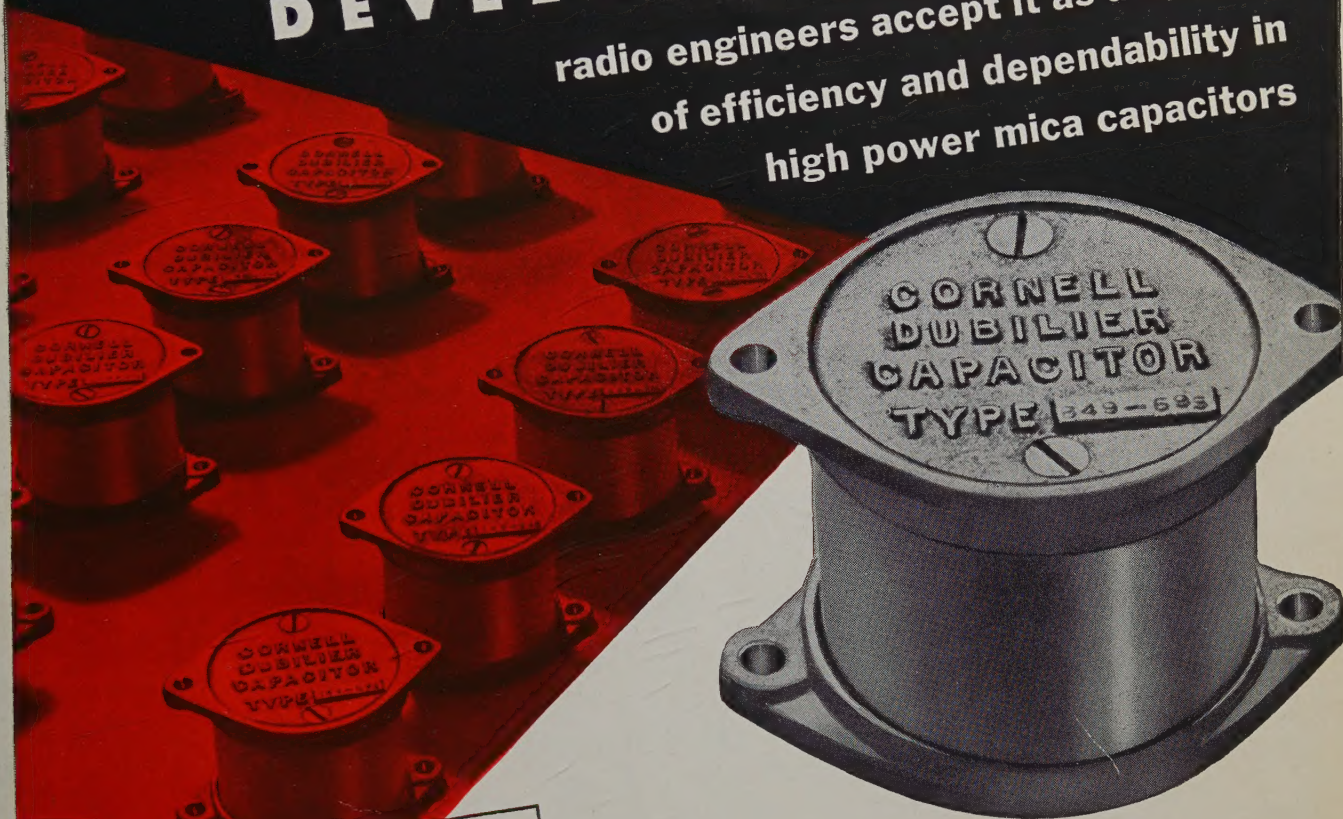
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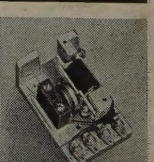
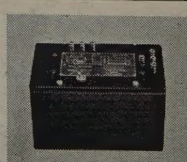
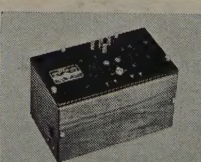
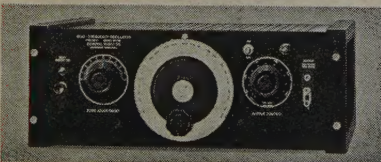
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